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Portland District

Mount St. Helens Ecosystem Restoration General Reevaluation Study Reconnaissance Report

Sediment Retention Structure on the North Fork Toutle River

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Abbreviations and Acronyms

Corps	U.S. Army Corps of Engineers
cfs	cubic feet per second
cy	cubic yard(s)
DEM	Digital Elevation Model
ESA	Endangered Species Act
ESU	Evolutionarily Significant Unit
fps	feet per second
FCF	fish collection facility
FCSA	Feasibility Cost Sharing Agreement
HDPE	high density polyethylene
LCFRB	Lower Columbia Fish Recovery Board
LCSCI	Lower Columbia Steelhead Conservation Initiative
NMFS	National Marine Fisheries Service
NPCC	Northwest Power Conservation Council
PCA	Project Cooperation Agreement
PE	passage efficiency (for fish)
PFC	proper functioning condition
RM	river mile(s)
SASSI	Washington State Salmon and Steelhead Stock Inventory
SRS	sediment retention structure
TE	trap efficiency (for fish)
TIN	Triangulated Irregular Network
WDF	Washington Department of Fisheries (now WDFW)
WDFW	Washington Department of Fish and Wildlife
WDW	Washington Department of Wildlife (now WDFW)

English to Metric Conversion Factors

To Convert From	To	Multiply by
feet (ft)	meters	0.3048
miles	kilometers (km)	1.6093
acres	hectares (ha)	0.4047
acres	square meters (m^2)	4047
square miles (mi^2)	square kilometers (km^2)	2.590
cubic feet (ft^3)	cubic meters (m^3)	0.02832
feet/mile	meters/kilometer (m/km)	0.1894
cubic feet/second (cfs or ft^3/s)	cubic meters/second (m^3/s)	0.02832
degrees fahrenheit (°F)	degrees celsius (°C)	(Deg F - 32) x (5/9)

Executive Summary

The purpose of the General Reevaluation Study Reconnaissance study is to determine if there is a federal interest in pursuing ecosystem restoration actions in the Toutle River watershed, while maintaining Congressionally authorized levels of flood protection for communities along the Lower Cowlitz River. The Toutle River watershed encompasses about 512 square miles primarily in Cowlitz County, Washington. The Toutle River drains the north and west sides of Mount St. Helens and flows generally westward towards the Cowlitz River. The three primary drainages in the watershed include the North Fork Toutle River, South Fork Toutle River, and Green River. Most of the North and South Forks were impacted severely by the 1980 eruption of Mount St. Helens and the resulting massive debris torrents and mudflows.

A sediment retention structure (SRS) was constructed on the North Fork Toutle River 5 years following the 1980 Mount St. Helens eruption in an attempt to prevent the continuation of severe downstream sedimentation of stream channels, which created flood conveyance, transportation, and habitat degradation concerns. The SRS totally blocked volitional upstream access to as many as 50 miles of habitat for anadromous fish. To mitigate for this effect to these fish, the U.S. Army Corps of Engineers funded habitat enhancements (development of off channel rearing areas), hatchery supplementation at Green River Hatchery, and construction of a fish collection facility (FCF) below the SRS to trap and haul salmonids to tributaries above the SRS.

The Toutle River system historically supported populations of several salmonid species that are currently listed as threatened under the Endangered Species Act including winter steelhead (*Oncorhynchus mykiss*), coho salmon *(Oncorhynchus kisutch)*, spring and fall Chinook salmon (*Oncorhynchus tshawytscha*), and chum salmon (*Oncorhynchus keta*). The North Fork Toutle historically provided productive habitat for these species. The reaches with the most restoration potential are located just downstream of the Green River confluence and further upstream on the North Fork between Hoffstadt Creek and Castle Creek.

Current conditions at the SRS were found to provide the potential for ecosystem restoration opportunities including upstream fish passage. The report addresses the existing fish passage limitations in the North Fork Toutle River as related to the trap-and-haul operations at the FCF and the inability of the SRS to volitionally pass fish. Connectivity/fish habitat restoration is specifically addressed for the sediment plain upstream of the SRS and for the Toutle River below the SRS. Also addressed is the broader issue of what ecosystem restoration efforts could be effective in the Toutle watershed independent of the federal authority or who would be the responsible party for implementation.

Determining the environmental benefits under current conditions was based on three main components:

- The percent of fish that successfully pass above the SRS with a given alternative.
- The effects of the trap-and-haul program on fish that successfully pass above the SRS (represented as percent of fish that are negatively affected by the operations).
- The effect of episodic high sediment loads on the successful return of adult fish.

Estimates for both steelhead and coho were made separately and the values were averaged for an overall percentage to come up with an environmental output improvement value. There is a large amount of uncertainty and variability around these estimates as data is limited but every effort was made to ensure that the values were treated consistently. Under existing conditions and considering the current status of the trap-and-haul operations, it was estimated that there is about 42% to 64% transport/passage for steelhead and 35% to 53% transport/passage for coho salmon. A range of potential ecosystem restoration measures and the associated costs were identified and compared to existing conditions. The following table summarizes the net increase in outputs, total estimated costs, relative cost per output, and the ranking order for each potential ecosystem restoration alternative.

Ranking of Potential Ecosystem Restoration Alternatives

Alternative	Net Increase in Outputs	Total Estimated Cost ($) (not annualized)	Relative Cost/Output ($)	Rank
BASELINE/NO ACTION (existing trap & haul after Nov 2006 high water event) = 44%	---	---	---	---
IMPROVE FALLS/SPILLWAY + FIX FCF	15.5	2,315,000	149,355	5
IMPROVE FALLS/SPILLWAY + FIX FCF + PILE DIKES	17.5	4,115,000	235,143	10
IMPROVE FALLS/SPILLWAY + REMOVE FCF BARRIER	20.5	1,700,000	82,927	3
IMPROVE FALLS/SPILLWAY + REMOVE FCF BARRIER + PILE DIKES	23.0	3,500,000	152,174	6
FISH LADDER AT SPILLWAY	not feasible	not feasible	not feasible	---
FIX EXISTING FCF	11.5	2,015,000	175,217	8
FIX FCF + NEW RELEASE SITE	18.0	2,115,000	117,500	4
FIX FCF + NEW RELEASE SITE + PILE DIKES	19.0	3,915,000	206,316	9
FIX FCF + IMPROVE TRIBUTARY SITES	14.0	2,215,000	158,214	7
FIX FCF + IMPROVE TRIBUTARY SITES + PILE DIKES	16.0	4,015,000	250,938	11
NEW FCF	30.0	12,900,000	430,000	15
NEW FCF + NEW RELEASE SITE	37.0	13,000,000	351,400	12
NEW FCF + NEW RELEASE SITE + PILE DIKES	39.0	14,800,000	379,500	13
NEW FCF + IMPROVE TRIBUTARY SITES	32.0	13,100,000	409,375	14
NEW FCF + IMPROVE TRIBUTARY SITES + PILE DIKES	34.0	14,900,000	438,235	16
NEW RELEASE SITE (can be stand alone if current FCF can function as it did pre-Nov 2006)	10.0	300,000	30,000	1
IMPROVE TRIBUTARY SITES (can be stand alone if current FCF can function as it did pre-Nov 2006)	5.0	400,000	80,000	2
PLANTINGS AT CONFLUENCES	---	2,050,000	---	---
OFF-CHANNEL BACKWATER HABITAT (Toutle River below SRS)	---	2,250,000	---	---

FCF = fish collection facility; SRS = sediment retention structure

Based on this preliminary analysis it appears there are several potential combinations of restoration measures to consider for implementation. The No Action Alternative (baseline, existing trap-and-haul operation) provides existing levels of output (about 44%) at no increased cost. Based on the cost estimates and output estimates, it appears that after the No Action Alternative, the best investment based on relative cost per output is the new release site. After that, improving tributary sites or improving the SRS spillway and removing the FCF barrier are the lowest cost per output. There is a significant breakpoint where costs per output increase when the cost of constructing a new FCF is added to the mix.

The Reconnaissance Report identified a range of possible alternatives that could provide benefits to anadromous fish species in the Toutle River watershed that are currently listed as threatened under the Endangered Species Act. Based on this preliminary assessment, a federal interest was established to pursue upstream fish passage improvements and ecosystem restoration measures in the Toutle River watershed. However, there are inherent risks and uncertainties that will need to be considered. Further study may identify reasons that preclude the implementation of fish passage improvements identified in the Reconnaissance study. Erosion and sediment movement into the North Fork Toutle River drainage continues to be significant and unpredictable. Consequently, there is a risk associated with investing in ecosystem restoration measures for the Mount St. Helens Project due to the instability of the North Fork Toutle River drainage and continuing sedimentation effects caused by the 1980 eruption of Mount St. Helens. It is anticipated that all ecosystem restoration work will focus on near-term actions to sustain and improve access to the tributary habitat above the SRS located on the North Fork Toutle River. In the future, the North Fork Toutle River system may become stable enough to consider a broader range of ecosystem restoration measures.

Mount St. Helens Ecosystem Restoration General Reevaluation Study Reconnaissance Report

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1. STUDY AUTHORITY

The Energy and Water Development Appropriations Act of 2006 (Public Law 109-103, November 19, 2005) provided funding for the Chief of Engineers, ". . . to conduct a General Reevaluation Study on the Mount St. Helens project to determine if ecosystem restoration actions are prudent in the Cowlitz and Toutle watersheds for species that have been listed as being of economic importance and threatened or endangered" (119 Stat. 2249).

2. BACKGROUND

The Toutle River watershed primarily drains the northwest and southwest slopes of Mount St. Helens and has a total drainage area of about 513 square miles at its confluence with the Cowlitz River. The May 18, 1980 eruption of Mount St. Helens dramatically altered the hydraulic and hydrologic regimes of the Cowlitz and Toutle River valleys. Ashfall and the lateral blast from the eruption produced immediate and long term effects on the hydrology of the Toutle watershed by changes in the land cover and runoff characteristics. The excess of sediment produced by the eruption and its aftermath was deposited downstream in the lower Toutle, Cowlitz, and Columbia rivers. The rapid influx of sediment caused reduced the channel capacities of the rivers affected. This left the communities of Castle Rock, Lexington, Kelso, and Longview in Washington with the potential of major flooding even with normal runoff. Emergency measures were implemented by the U.S. Army Corps of Engineers (Corps) under authority of Public Law 99-88 (August 15, 1985) and interim flood control measures were implemented under authority of Public Law 98-63 (July 30, 1983). Temporary debris or check dam type structures were constructed across the North Fork Toutle River (N-1) and South Fork Toutle River (S-1) to immediately reduce the volume of sediment delivered to the Cowlitz; levees were raised along the Lower Cowlitz River to prevent flooding; and the Columbia River was dredged to eliminate the threat to navigation.

Long-term sediment control facilities were constructed under Supplemental Appropriations Act of August 15, 1985 (Public Law 99-88). The project was designed to have a life of 50 years over the period 1985 through 2035. Project performance projections and proposed modifications are made for the time period ending in the year 2035. The Corps was authorized to construct and operate a sediment retention structure (SRS) near the confluence of the Toutle and Green rivers (see cover photo). The SRS is located at river mile (RM) 13.2 on the North Fork Toutle River, 30.5 miles upstream of the mouth of the Toutle River. The Toutle River is tributary to the Cowlitz River (RM 20.0), which flows into the Columbia River near the City of Longview, Washington. The SRS was constructed to allow downstream fish passage but is currently a barrier to upstream migrating adult salmonids. The SRS totally blocks volitional access to as many as 50 miles of upstream habitat for anadromous fish. The Toutle River system historically supported populations of several salmonid species currently listed as threatened under the Endangered Species Act (ESA) including winter steelhead, coho salmon, spring and fall Chinook salmon, and chum salmon.

The SRS consists of an earthen dam that is 125-feet above the original stream bed and 1,800-feet long, with a concrete outlet works and a spillway at its north end (see cover photo). Since 1987, the SRS has prevented an enormous quantity of sediment from traveling down the North Fork and into the Toutle, Cowlitz, and Columbia rivers. An estimated 105 million cubic yards of sediment have settled out in the 4-mile long reach upstream of the SRS (Figure 1). The design of the SRS anticipated that in the future, the outlet structure through which water and fish exited to the channel below would become closed off due to sediment infill behind the structure (Corps 1985). This occurred in 1998 and the North Fork Toutle River now flows over the SRS spillway. This change in condition provides the potential to provide for volitional upstream fish passage through the SRS to valuable upstream habitat and eliminate the problems associated with collecting and trucking the fish to upstream release sites.

Figure 1. Sediment Plain Upstream of SRS (seen in the distance)

Source: Steward and Associates

The SRS spillway is a 2,200-foot long, 400-foot wide, unlined, rough-bed channel with a 7% gradient (Figure 2). High flows in 1996 damaged the spillway and caused a 6-foot vertical drop (falls) at the downstream end of the spillway. In response to the damage, the Corps constructed a weir 1,000 feet downstream of the crest to prevent down-cutting, and made minor structural repairs to the spillway. Currently, water flows through a series of high-velocity cascades and depending on flow levels, over shallow sheet-flow areas before ending in the 6-foot vertical drop at the spillway's downstream end. The water continues downstream through a combination of riffles, runs, and cascades and over a concrete velocity barrier at the fish collection facility (FCF) before merging with the Green River.

Figure 2. Middle Section of the Spillway on the North End of SRS at Late Summer Baseflow

Source: Steward and Associates

As mitigation for the SRS, a trap-and-haul FCF was funded and constructed by the Corps on the North Fork Toutle River 1.3 miles downstream from the SRS to facilitate fish passage (Figure 3). The FCF was turned over to the State of Washington to operate and maintain. Adult steelhead trout (*Oncorhynchus mykiss*) and coho salmon *(Oncorhynchus kisutch)*, both threatened species under the ESA, are collected at the FCF. Fish are collected by diverting a portion of the river above the FCF into a fish ladder. Fish are attracted by this flow into the ladder and move up into a collection pond. Fish are then moved into transport tanks on trucks and taken to two upstream release locations (Hoffstadt and Alder creeks). Transported fish are released randomly in each stream without knowledge of their stream of origin. Large sediment volumes in the North Fork Toutle River have contributed and continue to contribute to FCF operational problems.

Figure 3. Fish Collection Facility Downstream from the SRS

Source: Steward and Associates

Radio-tagging and tracking adult coho salmon and steelhead was conducted in the North Fork Toutle watershed from fall 2005 through summer 2006. The study was a collaborative effort with multiple agencies and interest groups, including the Cowlitz Tribe, U.S. Geological Survey, Washington Department of Fish and Wildlife (WDFW), Corps, Weyerhaeuser, and the U.S. Forest Service. This preliminary study and proposed additional work is an important source of information as to how and where to pursue long-term salmon recovery in the North Fork Toutle watershed in the context of Cowlitz Basin-wide salmon recovery.

Recent sediment data collection and analysis work has identified increased potential threat of flooding due to the build-up of sediment in the lower Cowlitz River. An interim dredging measure is proposed in 2007-2008 in the lower Cowlitz River to maintain authorized flood protection levels for four communities along the lower Cowlitz River (Kelso, Longview, Lexington, and Castle Rock). Additional studies are underway to determine if long-term sediment control measures are necessary to deal with the sediment load through 2035, and to maintain Congressionally authorized levels of flood protection for the communities along the lower Cowlitz River. It is important to note that the actual ability to implement potential ecosystem restoration actions would be contingent upon the decisions made in response to these ongoing flood protection studies, and what modifications to the SRS and/or FCF can be agreed upon by the Corps and the State of Washington. The original local cooperation agreement for the Corps to construct the fish collection facility, and the State of Washington to operate and maintain the facility, was signed on April 26, 1986.

3. STUDY PURPOSE AND SCOPE

The purpose of this reconnaissance report is to determine if there is a federal interest in pursuing ecosystem restoration actions in the Toutle River watershed, while maintaining the authorized levels of flood protection to communities along the Lower Cowlitz River. Current conditions at the SRS may now provide the potential for ecosystem restoration opportunities including upstream fish passage. This report addresses the existing fish passage limitations in the North Fork Toutle River as related to the trap-and-haul operations at the FCF and the inability of the SRS to volitionally pass fish. Also, connectivity/fish habitat restoration is specifically addressed for the sediment plain upstream of the SRS and for the Toutle River below the SRS.

This report also addresses the broader issue of what ecosystem restoration efforts could be effective in the Toutle watershed independent of the federal authority or who would be the responsible party for implementation. The North Fork Toutle Work Group was the impetus to initiate a study of ecosystem restoration efforts for the watershed. This informally organized group is composed of a variety of local organizations such as Friends of the Cowlitz and individuals that are interested in pursuing fish and wildlife restoration around Mount St. Helens. Information from meetings, a workshop, site visits, and other additional study information can be found in Appendix A. A database of current information relevant to restoration work in the basin is included in Appendix B. The report concludes by providing a recommendation as to what environmental restoration measures would be in the federal interest to consider for implementation.

4. LOCATION OF PROJECT/CONGRESSIONAL DISTRICT

The Toutle River watershed is located primarily in Cowlitz County, with some tributaries in Lewis and Skamania counties in Washington. The Toutle River enters the Cowlitz River about 5 miles upstream of Castle Rock, Washington. Primary tributaries to the Toutle River include the North Fork Toutle River, South Fork Toutle River, and Green River. The study area is located in the 3rd Congressional District of Washington State, and Congressman Brian Baird is the representative. The U.S. Senators from Washington State are Patty Murray and Maria Cantwell.

5. OVERVIEW OF EXISTING STUDIES, REPORTS, AND PROJECTS

Myriad efforts have been undertaken since the eruption of Mount St. Helens related to erosion and sediment management, flood protection, and fish passage/habitat issues. The major efforts completed or ongoing by the Corps and other agencies and groups that are pertinent to this ecosystem restoration study are summarized below. The *Mount St. Helens Information Database* is a more comprehensive accounting of data and information sources related to sediment, fish, and habitat restoration (see Appendix B). The database was developed by Steward and Associates for the Corps' Portland District.

5.1. Corps of Engineers Sediment Management

U.S. Army Corps of Engineers, November 1983. A Comprehensive Plan for Responding to the Long-term Threat Created by the Eruption of Mount St. Helens, Washington. This report evaluated five alternatives for sediment control and six alternative outlets for stabilizing the level of Spirit Lake.

U.S. Army Corps of Engineers, December 1984. Mount St. Helens, Washington Feasibility Report and Environmental Impact Statement, Toutle, Cowlitz and Columbia Rivers Vol. 1 and 2. This report identified the permanent sediment control plan and provided an assessment of the environmental impacts.

U.S. Army Corps of Engineers, October 1985. Mount St. Helens, Washington Decision Document, Toutle, Cowlitz and Columbia Rivers. This was the decision document used to develop a permanent solution to the sediment problem that resulted from the eruption of Mount St. Helens. Measures considered included a single SRS, dredging, and levee raises for communities in the Lower Cowlitz River valley. The recommended plan was a combination of SRS, minimal levee improvements, and dredging downstream from the SRS during construction and in later years when the SRS reservoir filled and sediment began to pass over the spillway.

U.S. Army Corps of Engineers, 1987. Mount St. Helens Sediment Control, Cowlitz, and Toutle Rivers, Washington. Design Memorandum No. 10, Sediment Retention Structure Fish Collection Facility. This design memorandum presented the description, criteria, and design of the FCF constructed by the Corps as mitigation for the SRS. It also discussed interim fish collection.

U.S. Army Corps of Engineers, April 2002. Mount St. Helens Engineering Reanalysis, Hydrologic, Hydraulics, Sedimentation, and Risk Analysis Design Documentation Report. This report reassessed the level of flood protection and determined the risk of flooding was high before the year 2035 at the lower Cowlitz River damage reaches. The study showed when the level of flood protection at the Castle Rock, Lexington, Longview, and Kelso levees would drop below the authorized levels of flood protection. In addition, basic physical and hydraulic data was developed to allow for further alternative analysis.

U.S. Army Corps of Engineers, December 2005. Cowlitz River Basin Hydrologic Summary, Water Years 2003-2004. This report summarized annual rainfall events and the largest instantaneous discharges at the Toutle River Tower Road station and at the Cowlitz River Castle Rock station. The report also showed the annual amount of sediment deposited upstream of the SRS and what is passed downstream.

U.S. Army Corps of Engineers, August 2006. Mount St. Helens Project, Cowlitz River Levee Projects—Level of Protection and Sedimentation Update. This report documented that flood protection provided by the levee projects along the lower Cowlitz River has been degraded by current sedimentation processes. The observed trend of continued loss of channel capacity was expected to continue and spread upstream, further reducing flood protection levels.

5.2. Fish and Fish Passage

Martin D.J., L.J. Wasserman, R.P. Jones and E.O. Salo, 1984. The Effects of the Mount St. Helens Eruption on Salmon Populations and Habitat of the Toutle River. Report FRI-UW-8412, University of Washington, School of Aquatic and Fisheries Sciences. Juvenile coho mortality during winter ranged from 62% to 83% in streams unaffected by the eruption and from 82% to 100% in streams affected by the eruption. Mortality increased with increases in severity of impact and was associated with channel stability, suspended sediment, and the amount of cover provided by large organic debris. Adult salmon spawned in unstable volcanic substrates with average concentrations of fine particles (<0.850 mm) ranging from 11.2% to 36.0% in 1981 and from 11.2% to 33.5% in 1982. Survival of eggs to hatching stage in volcanic substrate ranged from 50% to 95%. Successful reproduction observed in impacted streams was attributed to temporary groundwater upwelling. Adult salmon and steelhead that returned to the Toutle River were observed spawning in most tributaries formerly utilized before the eruption. The lack of instream cover provided by large organic debris was cited as the limiting factor for complete habitat recovery in the Toutle watershed.

Washington Department of Wildlife, Toutle River Fish Collection Facility Operation and Salmonid Investigations – 1989, 1990, 1991, 1992. The reports listed below provided information about the operation of the FCF including wild coho and steelhead released above the SRS. Juvenile density data (1989-1992) for steelhead, cutthroat, and coho salmon captured by electrofishing in several tributaries of the Toutle River watershed were reported. The results of creel surveys conducted in 1989-1992 on the South Fork Toutle River to assess angler use and catch rate from wild winter-run steelhead were reported. Tag returns from sport anglers were reported for 1991-1992.

- Loch, J.J. and D.R. Downing, 1990. 1989 Toutle River Fish Collection Facility Operation and Salmonid Investigations. Report 89-13.
- Loch, J.J and J.M. Pahutski, 1991. Toutle River Fish Collection Facility Operation and Salmonid Investigations, 1990. Report 91-13.
- Loch, J.J., 1992. Toutle River Fish Collection Facility Operation and Salmonid Investigations, 1991. Report 92-16.
- Loch, J.J. and J.N. Byrd, 1993. Toutle River Fish Collection Facility Operation and Salmonid Investigations, 1992. Report 93-5.

Olds, C.A., 2002. Fisheries Studies at the Sediment Retention Structure on the North Fork Toutle River 1993, 2001, 2002. Washington Department of Fish and Wildlife, prepared for the U.S. Army Corps of Engineers, Portland District. This report presented the results of fish studies conducted at the SRS. The studies used hatchery fish and likely presented a conservative estimate of SRS wild coho salmon smolt passage impact. The data indicated that 22% of wild smolts from upstream of the SRS were injured passing the SRS and FCF during emigration. Holding smolts 160 hours post treatment showed that treatments (passing spillway and FCF) did not appear to effect smolt survival in the short term. While many smolts that passed the spillway in 2001 had dorsal scrapes between the head and dorsal fin, no internal damage due to these scrapes was found. Actions that reduce spillway water velocities or suspended sediment need to be taken due to smolt passage impact and the conservation status of wild salmonids populations upstream of the SRS.

Northwest Power and Conservation Council, May 17, 2002. Draft Cowlitz River Subbasin Summary. The subbasin plan for the Cowlitz subbasin prepared through the Northwest Power and Conservation Council (NPCC) for the Bonneville Power Administration's Fish and Wildlife Program provided baseline information necessary for long-term implementation planning. The plans provided goals for fish, wildlife, and habitat; objectives to measure progress; and strategies to meet those objectives.

Lower Columbia Fish Recovery Board, December 15, 2004. Lower Columbia Salmon Recovery and Fish and Wildlife Subbasin Plan. Volume II – Subbasin Plan, Chapter E – Cowlitz, Coweeman and Toutle. This plan describes a vision, strategy, and actions for recovery plan for Chinook salmon, chum salmon, coho salmon, steelhead, and bull trout listed or under consideration for listing under the ESA. The plan for the Toutle River watershed describes implementation of a regional approach within the watershed, as well as assessments of local fish populations, limiting factors, and ongoing activities. The plan was developed in a partnership with the Lower Columbia Fish Recovery Board (LCFRB), NPCC, federal agencies, state agencies, tribal nations, local governments, and others. The plan also serves as the subbasin plan for the NPCC Fish and Wildlife Program to address effects of construction and operation of the FCRPS.

Bisson, P.A., C.M. Crisafulli, B. Fransen, R. Lucas, C. Hawkins, 2005. Responses of Fish to the 1980 Eruption of Mount St. Helens. In Ecological Responses to the 1980 Eruption of Mount St. Helens. V.H. Dale, F.J. Swanson, C.M. Crisafulli, eds. Springer, New York. This comprehensive report described the effects of the Mount St. Helens eruption on salmon and steelhead in the Toutle and Cowlitz River systems. It described fish passage issues at the SRS and FCF, as well as the recovery of fish habitat.

Scott, J.B. Jr., W.T. Gill (eds), July 21, 2006. Oncorhynchus mykiss: Assessment of Washington State's Anadromous Populations and Programs. Draft for Public Review and Comment. Washington Department of Fish and Wildlife, Olympia. This comprehensive report was designed to lay the foundation for the development of improved management plans that assure the productivity of Washington's native steelhead. Topics include population structure, diversity, and spatial structure; habitat, abundance, and productivity; artificial production; management; and additional challenges and opportunities. Through population viability analysis, the two steelhead populations – Coweeman winter population and the North Fork/mainstem Toutle winter population – were identified as high risk for extinction in the lower Columbia River region.

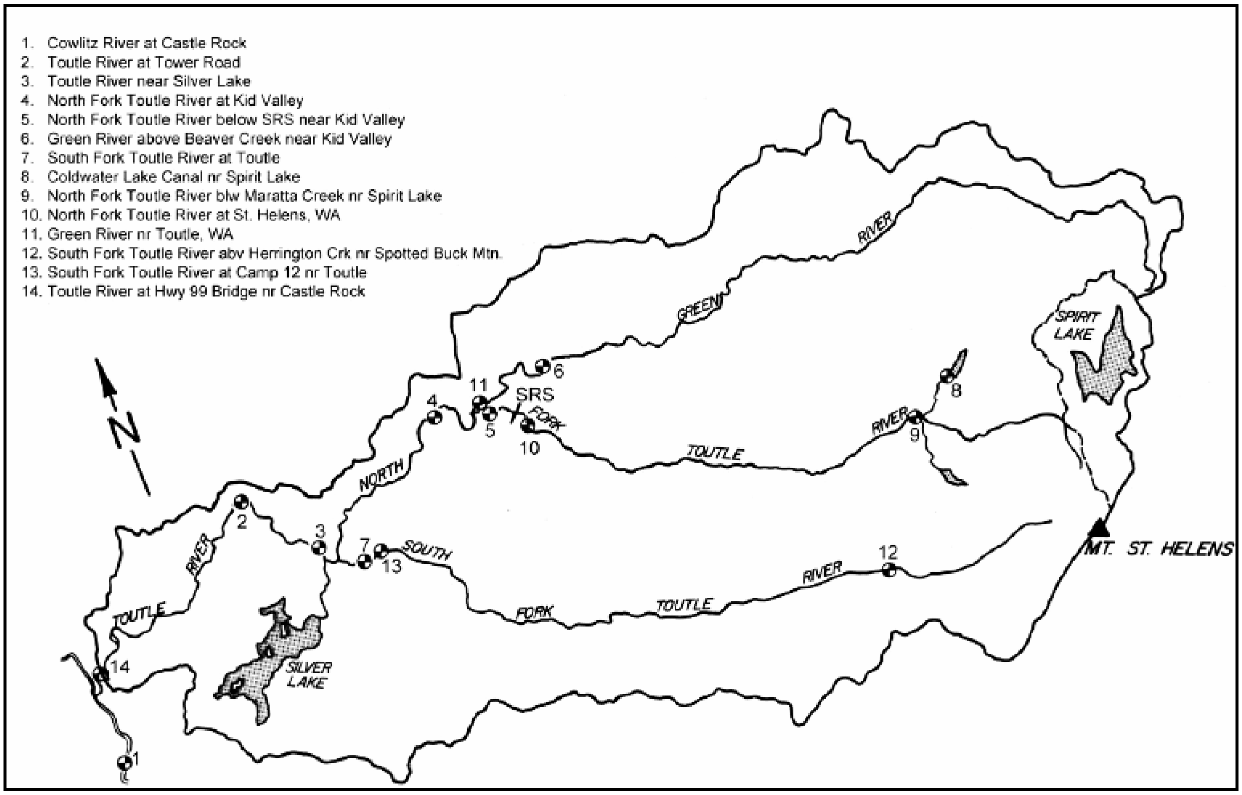
Kock, T., 2006. Migration Behavior of Radio-Tagged Adult Coho Salmon in the Upper North Fork Toutle River, Washington. Draft Report of Research. Telemetry was used to investigate movements of adult coho salmon above the FCF, the SRS, and in upstream reaches of the North Fork Toutle River and tributaries. The upstream passage of radio-tagged adult coho salmon was not observed into or through the SRS spillway. Upstream passage through the sediment plain may be flow dependent. Data suggested that the last downstream waterfall of the SRS spillway serves as an upstream barrier to passage of adult coho salmon. Tagging and monitoring efforts continue. Note that a report investigating migration behavior of adult steelhead is also being prepared.

6. TOUTLE RIVER WATERSHED EXISTING CONDITIONS

The Toutle River watershed encompasses about 512 square miles primarily in Cowlitz County, with some tributaries in Lewis and Skamania counties (Figure 4). The Toutle River enters the Cowlitz River at RM 20, just north of Castle Rock. Elevations range from near sea level at the mouth to over 8,000 feet at the summit of Mount St. Helens. The Toutle River drains the north and west sides of Mount St. Helens and flows generally westward towards the Cowlitz River. The watershed contains three primary drainages: the North Fork Toutle River, the South Fork Toutle River, and the Green River. Most of the North and South Forks were impacted severely by the 1980 eruption of Mount St. Helens and the resulting massive debris torrents and mudflows.

Forestry is the dominant land use in the Toutle River watershed. Commercial forestland makes up over 90% of the watershed. Much of the upper basin around Mount St. Helens is within the Mount St. Helens National Volcanic Monument and is managed by the U.S. Forest Service. A significant proportion of the forests to the north and west of Mount St. Helens were decimated in the 1980 eruption and are now in early seral or 'other forest' (bare soil, shrubs) vegetation conditions. Population centers in the watershed consist primarily of small rural towns.

Figure 4. Toutle River Watershed



6.1. Erosion and Sedimentation

The debris avalanche resulting from the May 18, 1980 eruption of Mount St. Helens deposited approximately 3.8 billion cubic yards of silt, sand, gravels, and trees in the upper 17 miles of the North Fork Toutle River. Lateral blast and mudflow deposits affected the South Fork Toutle River. Erosion of the debris avalanche and mudflow deposit has dramatically affected both the North and South Fork Toutle watersheds. Sediments eroded from the debris avalanche have impacts downstream on the Toutle, Cowlitz, and Columbia Rivers. The construction of the temporary N-1 debris dam and permanent SRS mitigated some of the negative effects of the increased sedimentation on the downstream reaches. As with many projects designed to control sediments, there have been some unintended morphological responses elsewhere in the watershed. These responses have ranged from increased bank erosion and channel instability to loss of connectivity of some of the smaller tributaries to the North Fork Toutle above the SRS.

6.1.1. Hydrologic Response to Mount St. Helens Eruption

The 1980 eruption of Mount St. Helens had the greatest impact on the North Fork Toutle River, which received the majority of the debris avalanche deposit (Figure 5). The Green River and South Fork Toutle River were affected by mudflow deposits. The effects of lateral blast and volcanic deposits altered the landscape characteristics of the three basins and changed the hydrologic characteristics. These effects were seen by increased peak streamflow that affected autumn and winter peaks for a period of 5 years post eruption. The immediate post-eruption changes were driven by modifications to hillslope hydrology (Major and Mark 2006). Table 1 shows the Toutle River drainage areas affected by the lateral blast and volcanic deposits.

Figure 5. Types of Deposits from the 1980 Mount St. Helens Eruption

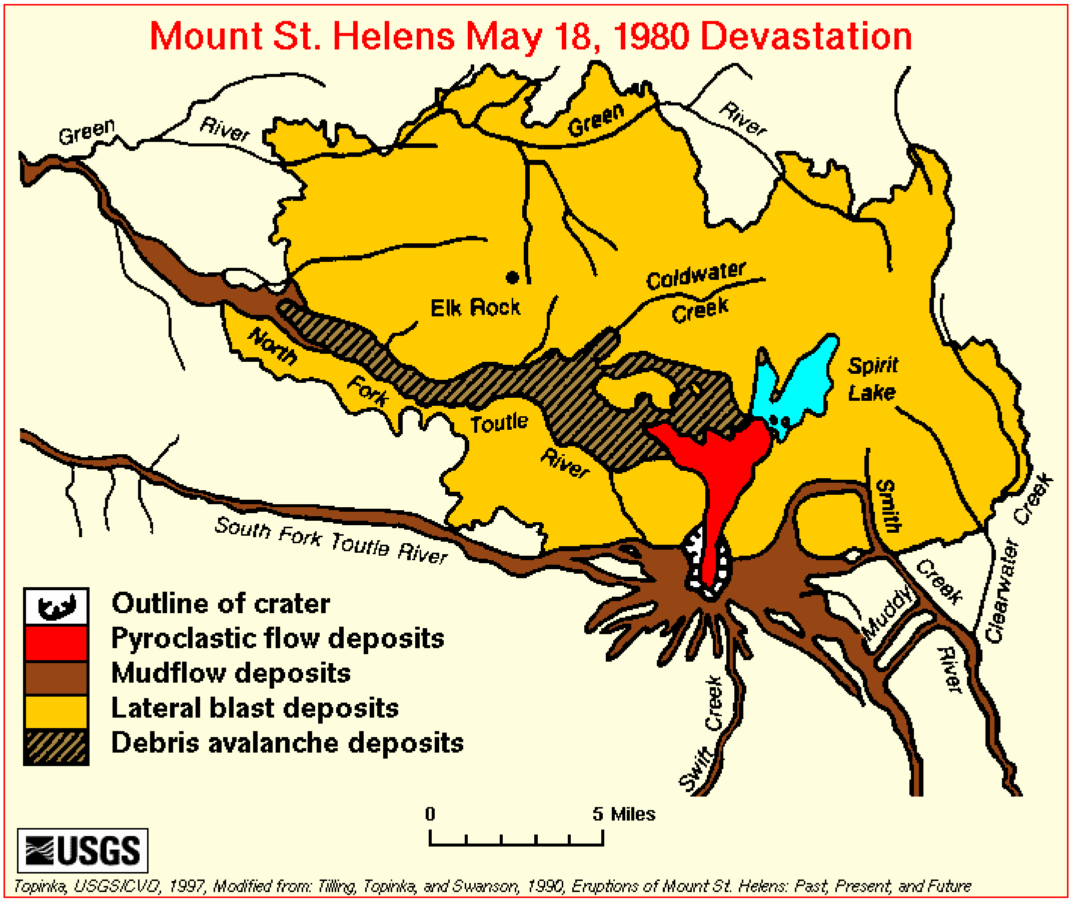


Table 1. Toutle River Basin Areas Impacted by the Mount St. Helens Eruption

Drainage	Total Drainage Area (mi^2)	Percent of Toutle River Drainage Area	Area Within Blast (mi^2)	Percent of Basin Within Blast
Green River	132	25.8	66	50.4
North Fork Toutle River above Green River	172	33.6	107	62.2
South Fork Toutle River	129	25.2	8	6.2
Spirit Lake	18	3.5	18	100.0
Lower Toutle River	61	11.9	0	0
Toutle River Basin	512	100.0	199	38.9

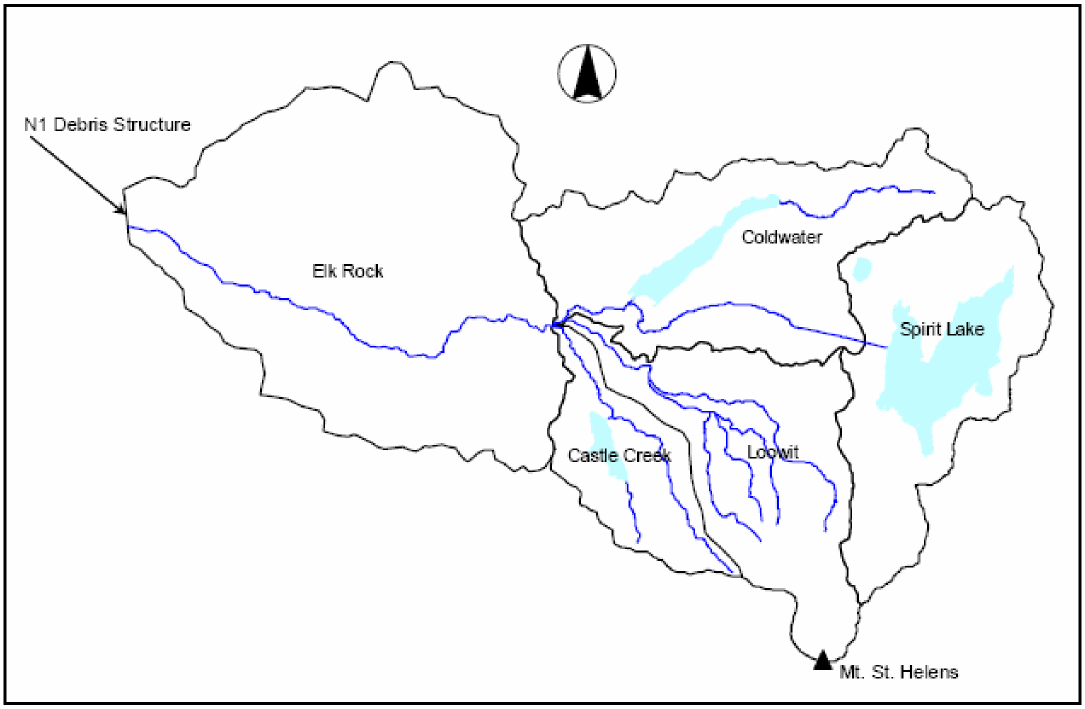
Source: Modified from Meyer and Dodge 1988.

Prior to the 1980 eruption, snow would accumulate in the Toutle River Basin at higher elevations. The frequency and magnitude of rain-caused floods became less significant as the winter season progressed. Melting of the snow pack would provide a significant contribution to the base flow during the spring months of March through June. Compared to pre-eruption conditions, the total snow pack on the mountain has been greatly reduced.

6.1.2. Erosion of Sediment from Debris Avalanche

Figure 6 shows the primary sediment sub-areas in the Toutle River watershed. Digital Elevation Models (DEMs) were developed from aerial photography for 1987 (pre-SRS) and 1999 in the form of Triangulated Irregular Networks (TINs) as part of the Corps' 2002 Mount St. Helens Engineering Reanalysis study. The DEMs were used to estimate the total erosion on the debris avalanche upstream of the SRS and the total deposition behind the SRS from 1987-1999 (Figure 7 and Table 2).

Figure 6. Primary Sediment Source Sub-areas above N-1 Debris Retention Structure

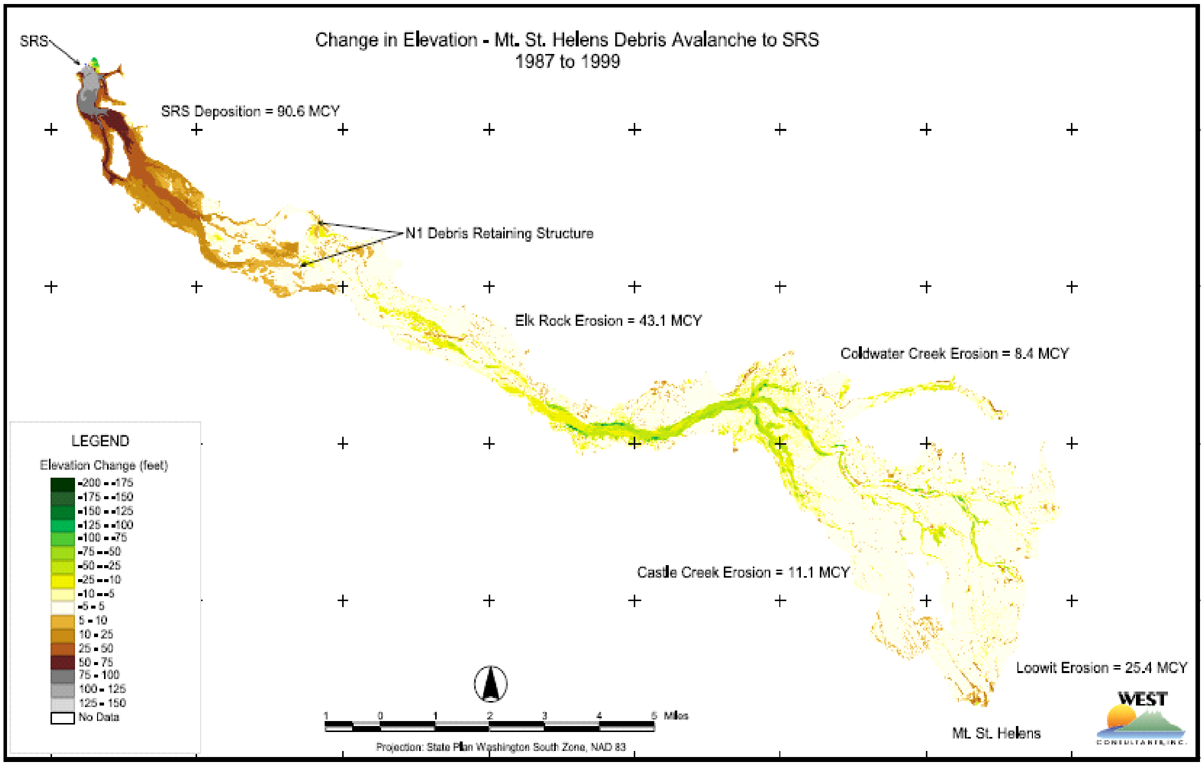


Erosion estimates were defined for each of the primary sediment sub-area on the debris avalanche. These sub-areas include Elk Rock, Coldwater, Castle, and Loowit creeks. Deposition estimates were developed for the North Fork Toutle River between the SRS and N-1 debris retention structure. The Elk Rock and Loowit sub-areas accounted for the majority of sediment yield to the SRS and North Fork Toutle below SRS; when combined, these two sub-areas account for 78% of total debris avalanche erosion from 1987 to 1999.

Table 2. Erosion Estimates Developed from 1987 and 1999 DEMs

Sediment Source Sub-area	Drainage Area (mi^2)	Measured Erosion (mcy)	Bulked Erosion (mcy)	Fraction of Total Erosion	Fraction of Drainage Area	Ratio of Total Erosion/Drainage Area
Elk Rock	42.28	43.1	50	49.0%	39.5%	1.24
Coldwater Creek + Spirit Lake	39.60	8.4	9.7	9.5%	37.0%	0.26
Castle Creek	7.92	11.1	12.9	12.6%	7.4%	1.70
Loowit	17.20	25.4	29.5	28.9%	16.1%	1.80
Total NF Toutle to N1	107	88	102.1	100%	100%	---

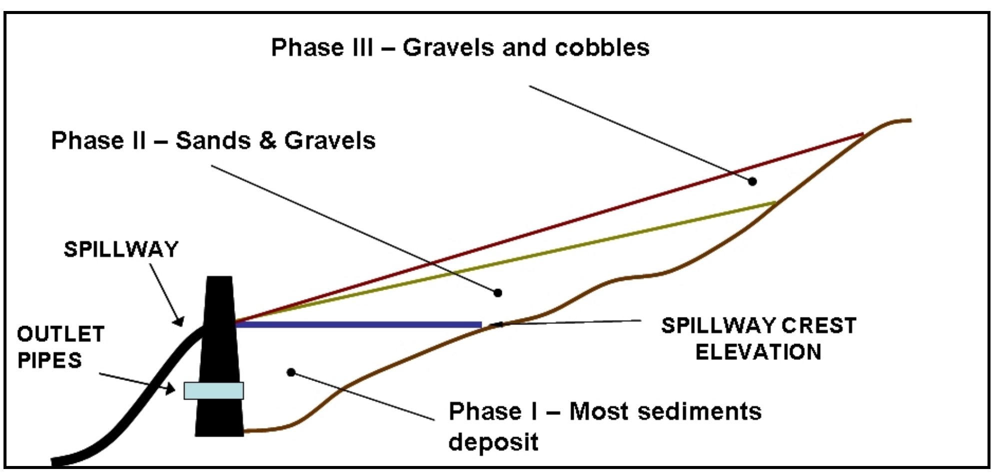
Figure 7. Erosion Estimates by Sub-area



6.1.3. Operation of the Sediment Retention Structure

The SRS was designed to operate in three general phases (Figure 8). The operational phases were based on the expected pattern of sediment deposition behind the dam and type/grain size of sediment to be trapped. Phase I was initiated when the SRS began trapping sediment behind the structure in November 1987.

Figure 8. SRS Design and Filling Pattern



For phase I operation, an impoundment was created by the dam and water was discharged through a series of outlet pipes (Figure 9). During phase I the majority of sediment moving through the system was deposited behind the SRS. Only silts, clays, and some very fine sand passed through the SRS via the outlet pipes. As sediments filled the impoundment, water was discharged through rows of outlet pipes at a higher elevation. Table 3 shows the dates when each row of outlet pipes were closed. By April 1998 the last row of outlet pipes was closed and nearly 90 million cubic yards (mcy) of sediment had filled behind the SRS. The upper row of pipes may be reopened, if necessary.

Figure 9. Phase I Operation, Photographs of Outlet Pipes and View Showing SRS

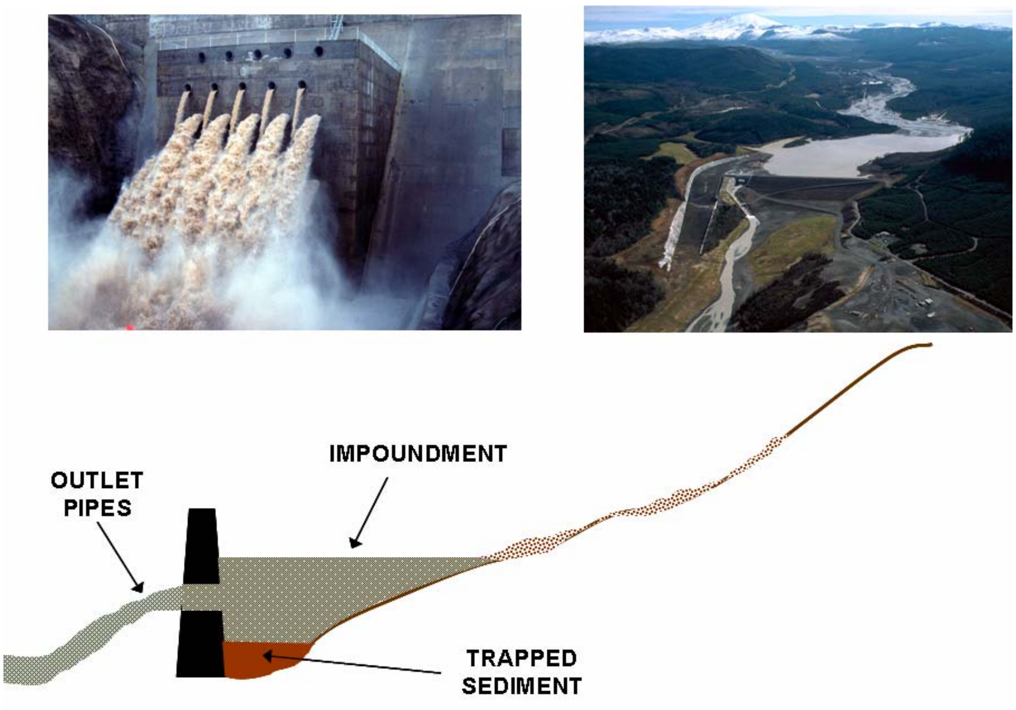


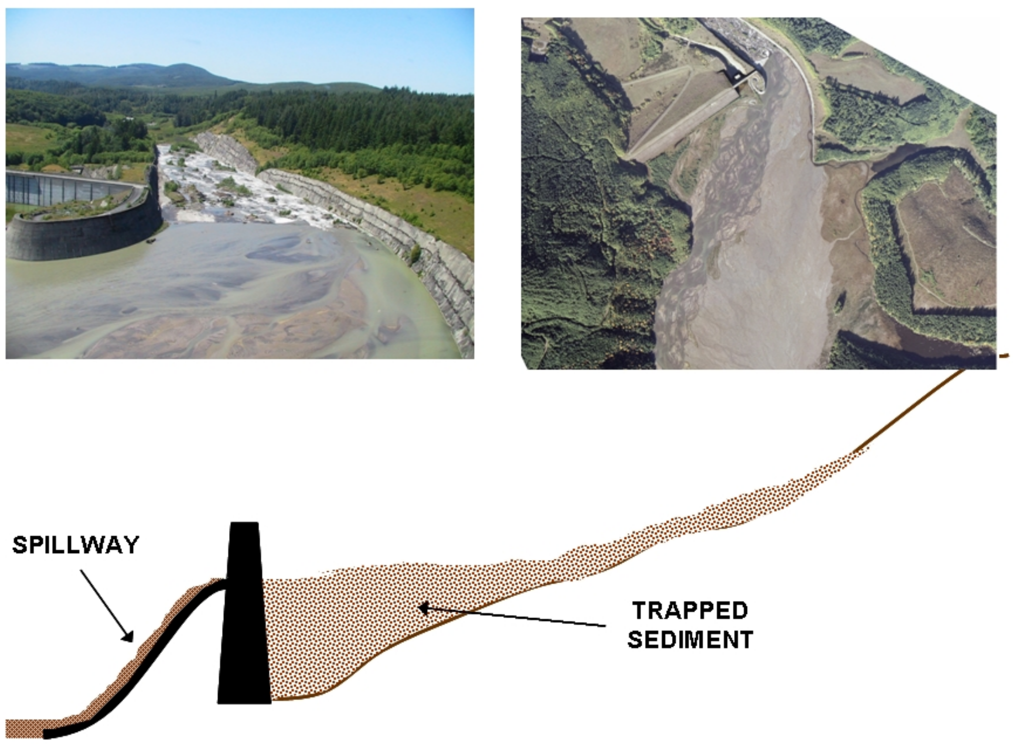
Table 3. Operational Data for SRS Outlets and Spillway

SRS Outlet	Dates of Last Operation
Bottom row	October 1991
Second from bottom	August 1993
Third from bottom	August 1995
Fourth from bottom	May 1997
Fifth from bottom	September 1997
Top row	April 1998 – available for use
Spillway	Permanently in use

The estimated sediment deposition was 90.6 mcy based on 1999 data developed by the Corps for the 2002 Mount St. Helens Engineering Reanalysis Study and was the volume used to estimate the SRS trap efficiency during phase I operation. The estimated sediment discharge passing the SRS for water years 1988 through 1998 is estimated at 10.4 mcy. Using these estimates, the total sediment managed by the project for this time period was 101 mcy (90.6 + 10.4 mcy). Thus, the SRS trap efficiency during phase I operation is estimated at 89.7% (90.6 mcy trapped/101 mcy total).

The second phase of operation began as the sediment reached the level of the spillway in 1998 (Figure 10). Since that date all North Fork Toutle River water flows through the spillway. Cumulative sediment deposition behind the SRS during phase II to date is estimated at 17.6 mcy, which brings the total deposition as of October 2006 to 105.3 mcy. The trap rate for phase II operation to date is 2.2 mcy/year (1998-2006). Data collected since the 2002 Mount St. Helens Engineering Reanalysis Study was used to update performance data on the project.

Figure 10. Phase II Operation, Photographs of Outlet Spillway and View of SRS



Trap efficiency of the SRS during the remainder of phase II and phase III operation is expected to be significantly less than phase I operation due to the lack of impounded water behind the sediment dam. The forecast estimates of annual sediment yield to the SRS over the current phase II operation (1998-2006) have ranged from 6.9 to 6.1 mcy and are based on average hydrology and average hydrology with an assumed declining rate of sediment yield based on watershed recovery from reforestation. Reforestation over the debris avalanche area would tend to reduce sediment yield. Trap efficiency during the current phase II operation is estimated to equal 33.9% based on the 2002 projections and observed deposition through 2006. Performance data for the SRS is summarized in Table 4.

Table 4. SRS Performance Data, 1987-2006

Operation Phase	Dates of Operation	Cumulative Deposition behind SRS (mcy)	Trap Rate (mcy/yr)	Trap Efficiency (%)
Phase I	Nov 1987 to Apr 1998	87.7	8.8	89.7*
Phase II	Apr 1998 to present*	105.3	2.2	33.9**

* Based on estimate of sediment discharge passing SRS from 1988-1998 made in the Corps 2002 Mount St. Helens Reanalysis Technical Report.
**Based on forecast sediment inflow used to estimate deposition behind through 2035.

6.1.4. Forecast Sediment Deposition

The Corps' Mount St. Helens Engineering Reanalysis Study that was completed in April 2002 provided a sediment deposition forecast for the SRS and performance estimates, based on sediment transport modeling of the SRS. The volume of available sediment from the debris avalanche was estimated at 3,700 mcy. The most recent estimate of the amount of this material that will erode and move through the system is 414 mcy.

The modeling for future conditions predicted that an additional 68 to 80 mcy of sediment transported through the system will deposit behind the SRS over the water years 2000 to 2035, assuming an incrementally reducing inflowing sediment load curve. If watershed recovery is not considered, then an additional 82 to 99 mcy of sediment is predicted to deposit over the same time period. Table 5 summarizes the modeling results and forecast data from the April 2002 reanalysis study.

Table 5. Summary of Modeling Results and Forecast Data, 2000 to 2035

SRS Performance	**Hydrologic Conditions**		
	Dry	**Average**	**Wet**
Forecast SRS trap efficiency 2000-2035	37%	39%	+30%
Sediment Flux Thru SRS	**Hydrologic Conditions**		
	Dry	**Average**	**Wet**
Forecast sediment yield to SRS 2000-2035 (tons)	263	283	243
Forecast sediment outflow past SRS 2000-2035 (tons)	161	197	154
Annual forecast sediment yield to SRS (tons)	7.5	8.1	6.9
Annual forecast sediment outflow past SRS (tons)	4.6	5.6	4.4
Sediment Deposition Upstream of SRS	**Hydrologic Conditions**		
	Dry	**Average**	**Wet**
Cumulative deposition 1987-2006 (mcy)	---	105.3	---
Forecast deposition 2000-2035 (mcy)	69.9	79.5	67.7
Annual rate, forecast over period 2000-2035 (mcy)	2.0/yr	2.3/yr	1.9/yr
SRS deposition 2000-2006 (mcy)	12.2	12.2	12.2
Annual rate, 2000-2006 actual (mcy)	---	2.0/yr	---
Total forecast deposition through 2035 (mcy)	164.2	173.8	162.0
Percent of design capacity (258 mcy)	64	67	63

As shown in Table 5, the greatest deposition behind the SRS occurs for average hydrologic conditions. For dry hydrologic conditions, flows are typically less than normal, resulting in a reduced sediment supply to the SRS. For wet hydrologic conditions, flows are typically greater than normal, resulting in a greater sediment supply to the SRS. However, the increased flows have a greater capacity to transport sediment past the SRS resulting in a trap efficiency of 30% as compared to 39% for average hydrologic conditions. Out-flowing sediment loads are approximately 22% greater and 5 percent smaller for wet and dry hydrologic conditions than average hydrologic conditions, respectively.

6.1.5. Impacts of Sedimentation from N-1 Structure to SRS

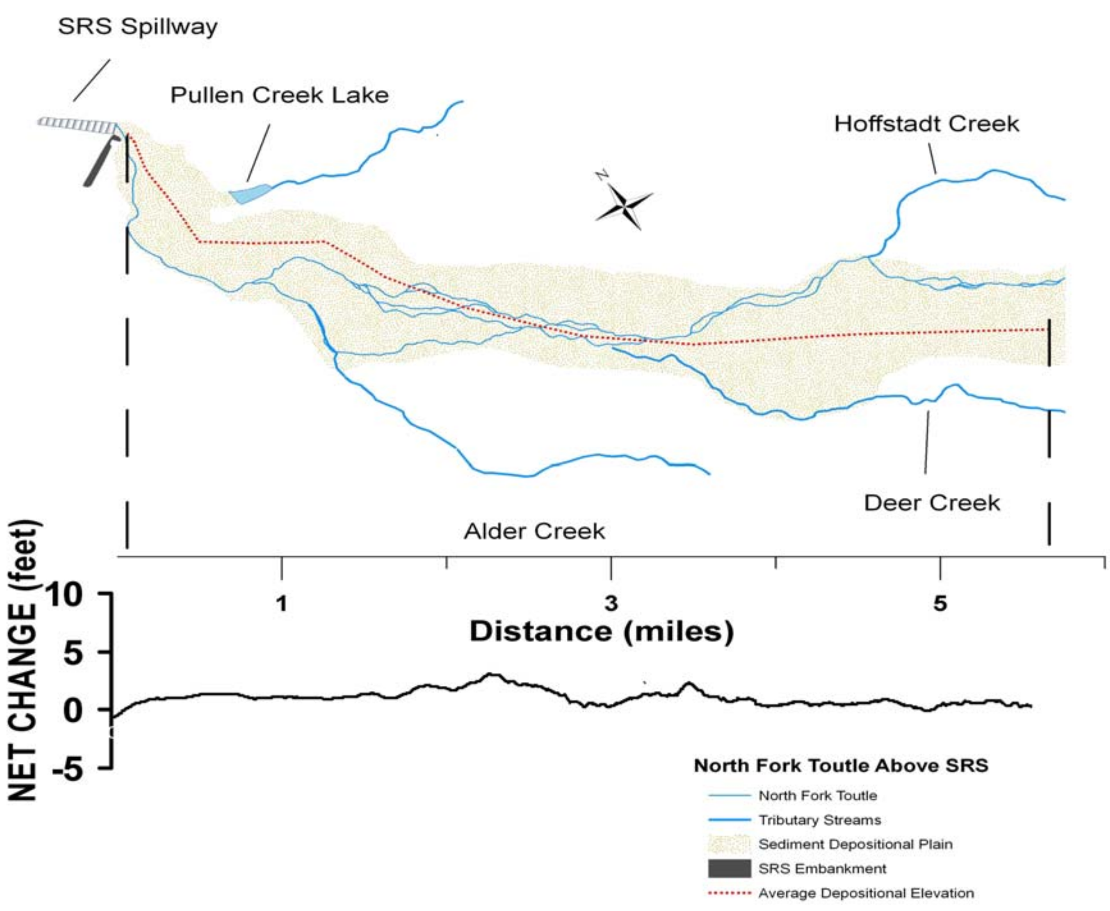
The SRS has trapped 105 mcy in the area behind the sediment dam to the base of the N-1 structure. This sediment deposition has affected the tributaries of the North Fork Toutle above the SRS. A qualitative assessment of the impacts to these tributaries is noted in Table 6.

Table 6. Sediment Deposition Impacts to Tributaries of the North Fork Toutle above SRS

Stream	Sediment Deposition Impacts	Elevation Change at Confluence (ft) 2005-2006
Pullen Creek	Deposition has caused a lake to form downstream, severing connection with North Fork Toutle.	1
Alder Creek	Sediment deposition has caused a delta to form at confluence. Connection with North Fork Toutle is transient and at times may consist of several smaller channels (braided).	1
Hoffstadt Creek	Currently maintaining stable connection to North Fork Toutle. Second confluence forms upstream at high flows from the North Fork Toutle.	0
Bear Creek	Connected to Hoffstadt Creek & affected by changes downstream at Hoffstadt-NF Toutle confluence; may serve as a high flow channel of the North Fork Toutle.	NA
Deer Creek	Within sediment deposition impacts reach; specific conditions were not identified in this study.	1

Figure 11 shows a general schematic of the tributary streams draining the North Fork Toutle through the sediment plain and a relative change in ground elevation (2005-2006) throughout this reach.

Figure 11. Tributaries to North Fork Toutle above SRS, Net Elevation Change 2005-2006



6.2. Fish Species

The Toutle River system historically supported populations of several salmon species currently listed as threatened under the ESA including winter steelhead (*Oncorhynchus mykiss*), coho salmon *(Oncorhynchus kisutch)*, spring and fall Chinook salmon (*Oncorhynchus tshawytscha*), and chum salmon (*Oncorhynchus keta*). Coastal cutthroat trout (*Oncorhynchus clarki clarki*) also was found in the Toutle River system. Much of the following information for fish species was taken from the Lower Columbia Fish Recovery Board's *Lower Columbia Salmon Recovery and Fish and Wildlife Subbasin Plan, Volume II – Subbasin Plan, Chapter E – Cowlitz, Coweeman and Toutle,* dated December 15, 2004 and the Northwest Power Planning Council's *Cowlitz River Subbasin Summary* (2002). Other information sources also are noted.

6.2.1. Winter Steelhead

The historical North Fork Toutle adult population of winter steelhead is estimated from 7,000-15,000 fish. Current natural spawning returns are 100 to 300 fish. It is estimated that from 1991 to 1996, none of the run was from hatchery fish (LCSCI 1998). Total escapement counts of wild winter steelhead in the North Toutle River from 1989-2001 have ranged from 18 fish in 1989 to 322 fish in 1992 (mean of 157 fish). In the Green River, spawning occurs in the mainstem, Devils, Elk, and Shultz creeks. In the North Fork Toutle River spawning occurs primarily in the mainstem, Alder, and Deer creeks. Currently, winter steelhead are managed for natural production with spawning occurring in Hoffstadt, Outlet, Alder, and Deer creeks. Spawning time is March to early June. Juvenile rearing occurs both downstream and upstream of the spawning areas. Juveniles rear for a full year or more before migrating from the Toutle basin.

Distribution

- Historically, steelhead were distributed throughout the mainstem Toutle, North Fork Toutle and Green Rivers.
- In the mainstem/NF Toutle, spawning occurs in the mainstem and Alder and Deer Creeks.
- In the Green River, spawning occurs in the mainstem and Devil, Elk, and Shultz Creeks.
- The 1980 eruption of Mount St. Helens greatly altered the habitat within the Toutle River Basin; the North Fork Toutle sustained the most significant habitat degradation.

Life History

- Adult migration timing for mainstem/North Fork Toutle and Green River winter steelhead is from December through April.
- Spawning timing on the mainstem/North Fork Toutle and Green River is generally from March to early June.
- Limited age composition data for Toutle River winter steelhead indicate that the dominant age class is 2.2 years (58.6%).
- Wild steelhead fry emerge from March through May; juveniles generally rear in fresh water for 2 years; juvenile emigration occurs from April to May, with peak migration in early May.

Diversity

- Mainstem/North Fork Toutle and Green River winter steelhead stocks designated based on distinct spawning distribution.

- Wild stock interbreeding with hatchery brood stock from the Elochoman River, Chambers Creek, and the Cowlitz River is a concern.
- Allele frequency analysis of Green River winter steelhead in 1995 was unable to determine the distinctiveness of the stock compared to other lower Columbia steelhead stocks.

Abundance

- In 1936, steelhead were observed in the Toutle River during escapement surveys.
- During period 1985-1989, an average of 2,743 winter steelhead escaped to the Toutle River annually to spawn.
- North Fork Toutle total escapement counts from 1989-2001 ranged from 18-322 fish (average 157 fish).
- Green River total escapement counts from 1985-2001 ranged from 44-775 fish (average 193 fish).
- Average escapement counts for mainstem/North Fork Toutle from 1994-1998 was 170 fish and from 1999-2004 was 257 fish.
- From 1991-1996, the winter steelhead run was believed to be completely from naturally produced fish.

Productivity & Persistence

- Live-spawning of Toutle River winter steelhead in 1982 and 1988 resulted in mean fecundity estimates of 2,251 and 3,900 eggs per female, respectively.
- Estimated potential winter steelhead smolt production for the Toutle River is 135,573.
- The NMFS Status Assessment estimated that the risk of 90% decline in 25 years was 0.71, the risk of 90% decline in 50 years was 0.93, and the risk of extinction in 50 years was 0.73 for the Green River winter steelhead.

Hatchery

- The Cowlitz Trout Hatchery, located on the mainstem Cowlitz at RM 42, is the only hatchery in the basin producing winter steelhead.
- Hatchery winter steelhead have been planted in the NF Toutle River basin from since 1953; broodstock from the Elochoman and Cowlitz Rivers and Chambers Creek have been used.
- Aside from small releases of 31,200 winter steelhead fry after the 1980 Mount St. Helens eruption, no hatchery winter steelhead have been released in the Green River.
- Hatchery fish contribute little to natural production of winter steelhead.

6.2.2. Coho Salmon

Coho are native to the South Fork Toutle River and spawn throughout the river and its tributaries. Some spawning areas were destroyed by the 1980 eruption of Mount St. Helens (WDF et al., 1993). South Fork Toutle coho natural spawners are a mixed stock of composite production. Current coho stocks are considered depressed based on chronically low production (WDF et al., 1993). Naturally spawning escapement estimates are not available. Hatchery coho production includes both “early” and “late” coho to meet harvest-management requirements. A number of tributaries in the Toutle River have good production potential. Among these are Johnson, Studebaker, Disappointment, and Herrington creeks (WDF et al., 1993).

6.2.3. Spring Chinook Salmon

Toutle River spring Chinook are not recognized by the Washington Department of Fish and Wildlife (WDFW) as a separate stock (WDF et al., 1993). In the early 1950s, annual spawning escapement was estimated to be 400 fish in the upper Toutle River (WDF 1951). The current estimated return is 164 fish (WDW 1990). The Toutle Hatchery produced spring Chinook from 1967 until 1980, when it was destroyed by the Mt. St. Helens mudflows (WDW 1990). Most Toutle spring Chinook were reared in Deer Springs Pond, which was destroyed in the winter of 1981-82 when a temporary flood-control dam was breached. Evaluation of the fish plants was not conducted, and returning adults were not captured at the hatchery. The primary management objective for the Toutle River is to produce 500 fish for the sport harvest. This would represent an estimated subbasin return of 1,697 fish and a total production of 2,976 fish (WDW 1990).

6.2.4. Fall Chinook Salmon

The historical Toutle adult population is estimated from 15,000-20,000 fish. The estimated annual escapement of fall Chinook in the Toutle and its tributaries in the early 1950s was 6,500. An average of 10,756 adults returned each year to the Toutle River basin from 1964 through 1979 (pre-eruption). The Toutle River has been stocked with fall Chinook since at least 1951 until 1980 (WDW 1990). Prior to the eruption of Mount St. Helens in 1980, significant fall Chinook natural spawning occurred in the lower 5 miles of the mainstem Toutle and in the lower North Fork Toutle. An estimated 80% of the total Toutle fall Chinook run spawned in the lower 5 miles of the mainstem Toutle (WDF 1951).

The eruption devastated much of the spawning area in the mainstem and North Fork Toutle. Current spawning primarily occurs in the lower Green below the North Toutle Hatchery and in the lower South Fork Toutle. The Toutle River Hatchery, located 0.5 miles up the Green River, began collecting brood stock again in 1990. Surplus hatchery fish were released upstream of the hatchery to spawn naturally. Brood stock has been from a mixture of sources since the 1980 eruption (WDW 1990). Current natural spawning returns range from 300 to 5,000 fish with the majority of hatchery origin fish spawning in the lower 0.5 mile of the Green River. Juvenile rearing occurs near and downstream of the spawning area. Juveniles emerge in early spring and migrate to the Columbia in spring and summer of their first year.

Green River fall Chinook are native to the Green River. About 20 miles of spawning and rearing area are available above the hatchery trap on the Green River (excluding tributaries; WDF 1973). The Green River fall Chinook natural spawners are an unknown stock. Natural spawning escapements from 1967-1979 averaged 3,025 fish with a low of 948 in 1977 and a high of 6,654 in 1972. Post eruption escapements in 1980 and 1981 were zero and 10 fish, respectively. Spawning ground counts were suspended until 1990, where the escapement was 123 fish in 1990 and 126 in 1991. Natural fall Chinook stocks were listed as depressed in SASSI (Washington State Salmon and Steelhead Stock Inventory) and show signs of a long-term negative trend (WDF et al., 1993).

Distribution

- Toutle River fall Chinook spawning distribution from 1964 to 1979 was estimated as 4.8% mainstem Toutle, 3.8% South Fork Toutle, 49.4% North Fork Toutle, and 42% Green River.
- Historical spawning areas in the mainstem Toutle, North Fork Toutle, and lower Green River were devastated by the 1980 eruption of Mount St. Helens.

- Records indicate most historical fall Chinook spawning occurred in the lower 5 miles of the mainstem Toutle River, but spawning spread as far upstream as Coldwater Creek on the North Fork Toutle River (46 mi from the river mouth).
- In the South Fork Toutle River, spawning primarily occurs from the 4700 Bridge to the confluence with the mainstem Toutle River (~2.6 mi).
- In the Green River, spawning primarily occurs from the North Toutle Hatchery to the river mouth (~0.6 mi).

Life History

- Columbia River fall Chinook migration occurs from mid August to early September, depending partly on early fall rain.
- Natural spawning occurs between late September and early-November, usually peaking in mid-October.
- Age ranges from 2-year-old jacks to 6-year-old adults, with dominant adult ages of 3 and 4.
- Fry emerge around early May, depending on time of egg deposition and water temperature; fall Chinook fry spend the summer in fresh water, and emigrate in the late summer/fall as sub-yearlings.

Diversity

- Considered a tule population within the lower Columbia River Evolutionarily Significant Unit (ESU).
- North Fork and South Fork Toutle River stocks designated based on distinct spawning distribution.

Abundance

- In 1951, the Washington Department of Fisheries (WDF, now WDFW) estimated fall Chinook escapement to the Toutle River was 6,500 fish.
- South Fork Toutle River spawning escapements from 1964-2001 ranged from 0-578 fish (average 177 fish).
- Green River spawning escapements from 1964-2001 ranged from 10-6,654 fish (average 1,900 fish).
- Hatchery production accounts for most fall Chinook returning to the Toutle River Basin; Chinook are re-establishing a population in the basin after the 1980 Mount St. Helens eruption.
- Hatchery produced adults comprise the majority of natural spawners in the Green and North Fork Toutle Rivers.

Productivity & Persistence

- Smolt density model predicted natural production potential for the Toutle River of 2,799,000 smolts.
- Juvenile production from natural spawning is presumed to be low.

Hatchery

- The North Toutle Hatchery (formerly called Green River Hatchery) is located on the lower Green River near the confluence with the North Fork Toutle River; operations began in 1956 but the hatchery was destroyed in the 1980 eruption of Mount St. Helens.
- The North Toutle Hatchery was renovated and began collecting brood stock again in 1990.

- Rearing ponds near the original hatchery site were developed after the eruption and began operation in 1985.
- Releases of fall Chinook in Toutle River Basin has occurred since 1951; current program releases 2.5 million sub-yearling fall Chinook annually; release data are displayed from 1967-2002.

6.2.5. Chum Salmon

The chum population in the Toutle watershed is considered part of the lower Cowlitz population. Chum were reported to historically utilize the lower Cowlitz River and tributaries downstream of Mayfield Dam. Lower Columbia River chum salmon run from mid-October through November; peak spawner abundance occurs in late November. Fry emerge in early spring and chum emigrate as age-0 smolts generally from March to May.

6.2.6. Coastal Cutthroat Trout

Coastal cutthroat abundance in the North Fork Toutle and Green rivers has not been quantified but the population is considered depressed. Cutthroat trout are present throughout the basin. Anadromous, fluvial, and resident forms of cutthroat trout are found in the basin. Anadromous cutthroat enter the Toutle from September to December and spawn from January through June. Most juveniles rear 2 to 4 years before migrating from their natal stream.

Little information is available for either the historic or present status of coastal cutthroat in the Toutle River. Lavier (1960) reported that 74 fish were captured at the Toutle River Hatchery in 1960. An estimated 40% of the 5,014 cutthroat harvested from the Cowlitz in 1979 were wild fish, many of which probably originated in the Toutle River (Tipping and Springer 1980). No hatchery plants of coastal cutthroat have been made in the Toutle River and none are anticipated.

All Toutle coastal cutthroat are considered one stock (WDFW 2000). Entry into the North Fork Toutle peaks between September and November, with a smaller number of fish moving throughout the winter (WDFW 2000). Spawning time occurs from January to June, and genetic data is unavailable for this stock (WDFW 2000). The status of the Toutle coastal cutthroat is depressed, based on chronically-low escapement measured at the Toutle River Fish Collection Facility and the North Toutle Hatchery, a long-term negative trend in the Columbia River catch from RM 72 to RM 48, and the habitat destruction from the 1980 eruption of Mount St. Helens (WDFW 2000). The stock is showing a slow recovery since 1980, but the escapement is chronically low. Another way to measure the status of this stock is by comparing the North Toutle Hatchery count. In 1959, 74 wild coastal cutthroat were captured during coho and Chinook collections. After 1991, annual counts have remained below six fish (WDFW 2000).

Distribution

- Anadromous forms have access to most of the watershed except upper tributary, high gradient reaches.
- Adfluvial forms are documented in Silver Lake.
- Resident and fluvial forms are observed throughout the subbasin.

Life History

- Anadromous, adfluvial, fluvial and resident forms are present.
- Anadromous river entry peaks from September through November.

- Anadromous spawning occurs from January through June.
- Fluvial and resident spawn timing is not documented but is believed to be similar to anadromous timing.

Diversity

- Distinct stock based on geographic distribution of spawning areas.
- No genetic sampling has been conducted.

Abundance

- No abundance information exists for resident and fluvial forms.
- Long term negative decline in the lower Columbia River cutthroat catch.
- North Toutle Hatchery counts have shown a steady increase since the eruption of Mount St. Helens in 1980, but escapement remains low.
- Chronically low escapement at Toutle River Fish Collection Facility (0 to 6 fish annually since 1991).

Hatchery

- North Toutle Hatchery raises Chinook and coho.
- Summer steelhead smolts from Elochoman or Kalama Hatchery are released into the South Fork and North Fork Toutle and Green Rivers annually.
- Silver Lake was stocked with rainbow trout prior to 1980.

7. PROBLEMS AND OPPORTUNITIES

7.1. Status and Condition of Fish

Salmonid species in Toutle River watershed include fall and spring Chinook, coho, and chum salmon, and winter steelhead trout. Extinction risks are significant for all species – the current health or viability ranges from very low for spring Chinook to low for fall Chinook, coho, and winter steelhead. Returns of fall Chinook, coho, and winter steelhead include both natural and hatchery produced fish.

Lower Columbia Salmon Recovery and Fish and Wildlife Subbasin Plan recovery goals call for restoring coho and winter steelhead to a high level of viability in the North Fork Toutle River. The 2004 Toutle Subbasin Plan used population assessments under different habitat conditions to compare fish trends and establish recovery goals. Fish population levels under current and potential habitat conditions were inferred using the Ecosystem Diagnosis and Treatment (EDT) model based on habitat characteristics of each stream reach and a synthesis of habitat effects on fish life cycle processes. Habitat-based assessments were completed in the Toutle basin for winter steelhead, fall and spring Chinook, and chum. It is important to note that spring Chinook have become functionally extinct in the Toutle subbasin. Model results indicate a decline in adult productivity for all species in the Toutle Basin. Declines in adult productivity from historical levels range from 70% for fall Chinook to greater than 90% for winter steelhead. Similarly, adult abundance levels have declined for all species. Current estimates of abundance are 44% of historical levels for fall Chinook, 13% of historical levels for winter steelhead, 11% of historical levels for coho and only 5% of historical levels for chum. Estimated diversity has also decreased significantly for all species in the Toutle Basin. Declines in species diversity range from 34% for fall Chinook, to greater than 70% for coho.

This sharp decline in diversity may be due to a dramatic loss of available habitats compared to pre-Mount St. Helens eruption conditions. The 1980 eruption may also contribute to the observed trends in productivity and abundance. Timber harvest and road building in the post-eruption years has further depressed the stocks and has limited the rate of recovery.

As with adult productivity model results in the subbasin plan, current smolt productivity is also sharply reduced as compared to historical levels. Current smolt productivity estimates are between 17% and 52% of historical productivity, depending on species. Smolt abundance numbers are similarly low, especially for chum and coho. Current smolt abundance estimates for chum and coho are at 13% and 10% of historical levels, respectively. Model results indicate that restoration of proper functioning condition (PFC) would have large benefits in all performance parameters for all species. For adult abundance, restoration of PFC would increase current returns by 107% for fall Chinook, by 255% for winter steelhead, by 496% for chum and by 600% for coho. Similarly, smolt abundance numbers would increase for all species. Coho would see the greatest increase in smolt numbers with a modeled 709% increase.

According to the Lower Columbia Fish Recovery Plan (LCFRB 2005), the abatement of fish passage and sediment problems at the SRS on the North Fork Toutle would have a tremendously positive impact on reach tiers and subwatersheds within the Toutle watershed that possess the greatest recovery potential. Actions that address passage and sediment problems at the SRS were given a high priority in the Recovery Plan.

7.2. Key Limiting Factors

7.2.1. North Fork Toutle

The North Fork Toutle historically provided productive habitat for winter steelhead, spring Chinook, and coho. Fall Chinook may also have utilized these reaches to some degree. The reaches with the most potential are located just downstream of the Green River confluence and further upstream on the North Fork between Hoffstadt Creek and Castle Creek (reach NF Toutle 13). Volitional passage is currently blocked just upstream of the Green River confluence by the SRS, created to retain eruption-related sediments following the 1980 eruption. North Fork Toutle reaches were severely impacted by mud and debris flows during the 1980 eruption, followed by intensive road building and timber harvests. The recovery emphasis is for restoration of watershed processes throughout the North Fork basin including addressing the dense road network and heavy harvests. Emphasis should also be placed on addressing the continued supply of sediment from the SRS, which has become a persistent limiting factor for fish in downstream reaches.

The SRS is also a source of fine sediment to the lower river. In addition, the ongoing erosion of material upstream of the SRS that moves through the structure has interfered with the fish collection facility just downstream of the structure. Addressing passage and sedimentation issues at the SRS will be a key component of salmon and steelhead recovery in the basin.

7.2.2. Sediment Retention Structure and Fish Collection Facility

The 1980 eruption of Mount St. Helens devastated fisheries resources in the North and South Fork Toutle River watersheds (WDW 1990; Lucas 1986; Jones and Salo 1986; Lisle et al., 1982; Collins and Dunne 1981). Tributaries in the upper North Fork Toutle watershed were completely destroyed as massive landslides and debris-flows traveled 13.5 miles down the North Fork (Jones and Salo 1986). Deposition of debris flows buried 23 square miles of terrain to an average depth of 150 feet, including more than 27 miles of anadromous stream habitat (Jones and Salo 1986). Many stream systems that were not directly affected by the debris flows were still blanketed with substantial amounts of ashfall and most of the vegetation in the watershed was blown down by the eruption (Lucas 1986).

The 1980 eruption of Mount St. Helens sent a tidal wave of melted ice and pulverized rock down the Toutle Valley into the Cowlitz River, and carried so much of this coarse sandy material and debris all the way to the Columbia River that dredging was required to clear the channel before river shipping could be resumed. Over 74 mcy of material had to be removed from the Cowlitz River within the first year after the 1980 eruption to maintain flood capacity (Cowlitz County 1983). Floodplain and wetland habitat along portions of the lower Cowlitz and Toutle Rivers was filled with the dredge spoils. Stream systems are recovering slowly from the effects of the eruption. However, elevated sediment loads, channel widening, lack of large woody debris, and riparian cover all remain problems today.

Large scale removal of this volcanic material in the Cowlitz River began at the lower end of the Toutle River by July 1980 and continued on down the Cowlitz River until engineers were reasonably confident that the cleared channel could handle expected winter flows without topping dikes and flooding Castle Rock, Longview, and Kelso. A dam to control sediment was then constructed further up the Toutle River by the Corps to prevent the re-silting of the dredged sections.

The SRS on the North Fork Toutle was constructed 5 years following the 1980 Mount St. Helens eruption in an attempt to prevent the continuation of severe downstream sedimentation of stream channels, which created flood conveyance, transportation, and habitat degradation concerns. Before the SRS was constructed a temporary sediment retention structure was built across the North Fork Toutle (N1) and dredging of sections of the streambed was initiated as an emergency measure (Figure 7). The original design capacity of the 6,100-feet-long (two sections) N1 structure was to store 6 mcy yards of sediment. The N1 structure breached several times after dredging behind the structure was terminated in 1981.

The Corps acquired a lease of the N-1 site from Weyerhaeuser, the underlying fee holder of the site. The lease term was for 5 years from July 1, 1980 to July 1, 1985, but the lease was terminated by the Corps on January 20, 1984. Currently the Corps has no property rights for use of this site. This information was obtained from Portland District real estate files; therefore, it is possible the ownership may have been transferred in the last few years. Any proposed modification of the N1 structure will require coordination and agreement with the current owner.

Once the N1 structure became ineffective in 1983, it became clear additional sediment control measures would be needed. Consequently, the Corps acquired, in fee simple, the land the SRS is constructed on, along with an easement over the impoundment area. The deed for the conveyance was filed in Cowlitz County by Washington State Department of Transportation. The SRS was constructed as part of a sediment management plan to mitigate potential flooding on the Cowlitz River from sediment migration created by the eruption and was expected to have a design life of 25 to 50 years. It also was built to have the capability for a future phased height increase.

Once in place, the SRS totally blocked volitional upstream access to as many as 50 miles of habitat for anadromous fish. To mitigate for this effect, Corps funded habitat enhancements (development of off channel rearing areas) for coho; hatchery supplementation at Green River Hatchery to raise coho, spring Chinook, and fall Chinook; and construction of a fish collection facility below the SRS to trap and haul salmon, steelhead, and coastal cutthroat to tributaries above the SRS.

Providing fish passage as part of the SRS construction was the primary mitigation recommendation of federal and state fish and wildlife agencies. Construction of a fish trap and haul facility was determined to be the most viable option. A unique agreement was reached with the State of Washington concerning federal and state participation in this project; for the fish trap, this agreement placed the responsibility for the construction of the trap on the Corps and all subsequent operation and maintenance of the trap upon the state. With this agreement, a cooperative design process was entered into which proved to be very time consuming. Consequently, it became apparent that the permanent trap could not be designed and built before SRS construction blocked fish passage and that an interim temporary trap would be needed. The temporary trap just below the SRS became inoperable its first day of operation due to sediment blockage. The location for the permanent trap site was moved downstream about a mile and a half. Final plans for the design proceeded with the understanding it would have to withstand the harsh conditions of the basin, resulting in a structure costing $6.7 million.

Until 1998, outmigrating juvenile fish could pass downstream through the SRS via the outlet works, a stacked series of 3-foot conduits, at all flows, and via the spillway during high water events. Survival of juveniles passing downstream through SRS via the outlet pipes was very low at times due to debris and high levels of suspended sediments. In 1997 modifications to the SRS spillway were made to enhance juvenile passage during high flows, including partially raising the crest of the spillway, building a plunge pool at the crest, and excavating a notch in the existing RCC fill halfway down the chute. In 1998 the outlet works was closed when the level of sediment above the SRS filled to near capacity and the spillway became the only route available for juvenile downstream passage. The spillway is a rough bed channel 2,200-feet long with a 7% slope, 400-feet across at the top and narrowing to 200-feet across at the bottom. The spillway was damaged by high water in 1996. Channel head cutting is arrested by concrete capping just below the spillway crest and construction of a notched concrete channel spanning weir 1,000 feet downstream of the crest. Much of the spillway is left as formed by instream flows, mostly high velocity cascades cut into bedrock, with some large shallow pools and three shallow sheet flow areas. During low flow periods [250 cubic feet per second (cfs)] water velocities average 5 feet per second (fps), with maximum velocities of 9 fps. At high flows of 1620 cfs (5% chance of exceedance flow) velocities can reach 19 fps. At the bottom of the spillway is a long, deep rapid ending in a 6 foot falls. The north bank of the waterfall has a cascade bypass section at 10% gradient. Below the spillway the river is a series of low gradient rapids and runs to the fish collection facility a mile downstream.

The North Fork Toutle River FCF was constructed by the Corps as mitigation for the impacts of the SRS. It was built to collect and separate fish as part of a trap and haul program for adult Chinook, steelhead, and cutthroat trout in the North Fork Toutle River above the SRS. The facility has been owned and operated by the WDFW since 1993. The intended operation was to collect fish at the FCF by diverting a portion of the river above the FCF into a fish ladder and back into the river below the barrier. Fish were to be attracted by this flow into the ladder and move up into a collection pond with an automated crowding screen. Crowded fish would be hand sorted, anesthetized in a tank, biological information is recorded, and fish are moved to transport tanks on trucks to be taken to release locations. Due to high sediment loads and stream flows, the FCF was frequently incapacitated and is in a serious state of disrepair.

In recent years, biologists from WDFW and volunteers operate the facility for 1 day per week during fall coho migration and winter/spring steelhead migration, often with fish trapped and held for up to 5 days before being transported and released. Fish are manually crowded, netted, and carried from the trap to a transport vehicle. Large amounts of sand must to be manually moved out of the trap at relatively frequent intervals and that process takes a considerable amount of time. Technical Advisory Group members with the WDFW state that the FCF is inoperable much of the time due to sediment problems and the lack of funding to remove the material. This has occurred at crucial times during adult fish migration, and they have been unable to allow any adult passage when heavy sediment loads are moving through the system.

There are also concerns that the flows through the plunge pool have altered enough to negatively affect adult attraction into the trap. The downstream lip of the plunge pool concrete, over which the river was expected to flow, has been undercut and parts of the apron have broken such that portions of the flow move laterally out of the plunge pool. This change in flow dynamics may keep fish from finding the attraction flow coming from the trap. Improvements made at the trap should increase adult fish collection efficiency and reduce stress and potential injury to fish, and could provide volitional passage.

7.2.3. Juvenile Passage Studies at SRS and Upstream Tributaries

The passage of downstream migrant juvenile salmonids in the North Fork of the Toutle River was a subject of concern since the SRS was first proposed in 1983. The NMFS proposed installing a gated lined low-flow channel cut in the spillway as an alternative to passage through the high velocity outlet works. Subsequently, a three-phase fish passage study was conducted that addressed juvenile downstream passage. The first two phases evaluated short-term survival and delayed mortality of outmigrating fish through the outlet works at the SRS. Lower than expected tag returns from these releases indicated that an unexplained mortality factor impacted these fish and that release timing and suspended sediment loads related to instream flows may have contributed to this mortality.

In 1998, after the outlet works was closed, juvenile passage occurred via the spillway. Washington Department of Fish and Game studies in 2001 and 2002 evaluated the cumulative effects of passage through the spillway and FCF on juvenile salmonids (Olds 2002). Transport, handling, and passage of hatchery raised Coho smolts released through the spillway or over the FCF dam downstream, did not appear to effect short term survival. Although around 22% of the smolts showed some signs of injuries passing through the spillway and FCF, nearly all of the injuries were superficial dorsal scrapes that healed quickly and did not effect survival for the 160 days they were held post treatment. Bioassay chamber results in 2002 again raised concerns about potential survival impacts from extended exposure to high suspended sediment loads.

Annual surveys of juvenile fish densities in Hoffstadt Creek by Weyerhaeuser indicate that despite continued releases of trap and haul coho adults into this stream, juvenile densities remain very low. Steelhead stocking in the same creek has resulted in successful spawning and production of juveniles, with juvenile steelhead densities increasing with the release of larger numbers of steelhead adults. The lack of success by coho could be a result of unsuccessful spawning or because fish leave the system after release. Another problem with this release site is its location above a natural barrier where resident cutthroat reside. Cutthroat are no longer found in the portion of the creek where the trap and haul fish are released but are still abundant upstream of the areas used by released steelhead.

Access to release sites can be problematic during high runoff conditions, good holding pools at or just below several of the release sites are limited, and the release hoses need improvements to reduce injuries and stress.

7.2.4. Adult Passage Studies at SRS

Historically as high as 11% of North Fork Toutle steelhead moved downstream after spawning to regain weight and return upstream to potentially spawn. Evaluations in 1990 indicated these fish may have difficulties in passing downstream through the conduit pipes of the outlet works where debris would often collect.

Currently, it is not clear to what extent the SRS spillway and the N1 structure are barriers to adult fish migrating upstream. Preliminary results from radio-telemetry studies found that some steelhead are capable of volitional passage up the SRS spillway, into spawning tributaries, and well above the N1 structure. Volitional upstream passage of adult coho appears to be blocked by the falls at the bottom of the SRS spillway. Adult coho and steelhead release just above the SRS into the braided sections of the North Fork Toutle River passed upstream into tributaries, with some fallback over the spillway. Most of this fallback appears related to releasing fish too close to the vicinity of top of the SRS spillway as the percentages dropped dramatically when the release site was moved upstream.

Concerns were raised about passage barriers related to high water temperatures and shallow water during low river flow periods in braided areas above the SRS. Rob Jones (NMFS) at a Toutle River/SRS Fish Passage Coordination Meeting in 1986 stated that often anadromous fish can recolonize such areas, even with periods of 70% fines in the suspended sediments and water temperatures that go above 80°F. Braiding and temperature concerns need to be considered with respect to the periods of time that adult or juvenile fish will likely be using those sections of the North Toutle above the SRS. Migration timing for adults runs from October into early June. Juvenile outmigration occurs primarily during April and May.

7.2.5. Confluence Connectivity/Fish Habitat

Although the North Fork Toutle River historically provided productive habitats for anadromous salmonids, productivity continues to remain limited due to eruption impacts. Sediment loads remain very high in the North Fork Toutle River above and below the SRS, and in the mainstem Toutle River below its confluence with the North Fork Toutle. Braided stream conditions and erosion continues to impact fish habitat in these channels under low-, medium-, and high-flow conditions.

7.3. Summary of Current Fish Status

The determination of environmental benefits under current conditions was based on three primary components:

- The percent of fish that successfully pass above the SRS with a given alternative.
- The effects of the trap-and-haul program on fish that successfully pass above the SRS (represented as percent of fish that are negatively affected by the operations).
- The effect of episodic high sediment loads on the successful return of adult fish.

Estimates for both steelhead and coho were made separately and the values were averaged for an overall percentage to come up with an environmental output improvement value. There is a large amount of uncertainty and variability around these estimates as data is limited but every effort was made to ensure that the values were treated consistently.

Overall, it has been estimated that under existing conditions, considering the current status of the trap-and-haul operations there is about 42% to 64% transport/passage for steelhead and 35% to 53% transport/passage for coho.

8. POTENTIAL MEASURES

This section describes the range of potential ecosystem restoration measures and the associated costs that have been identified. Note that the restoration measures associated with fish passage at the SRS and/or FCF would need to be completed before confluence connectivity/fish habitat actions should be implemented. In addition, maintaining authorized levels of flood protection for the communities along the Lower Cowlitz River must be fully understood and integrated into any ecosystem restoration plan.

8.1. Fish Passage Measures

8.1.1. <u>SRS Spillway Improvements</u>

Improve SRS Falls/Spillway. This fish passage measure requires removing the falls at the bottom of the spillway and creating lateral connections and resting pools on the spillway. The falls was formed in 1995 when high flows eroded the overburden beneath the shotcrete at the bottom of the spillway on the west side (Figures 12 and 13). This spillway improvement measure would remove the falls by excavating the rock bottom of the spillway back to a more gradual slope, and building fish passage features into the slope, such as resting pools. The estimated volume of rock excavation is about 1,000 cubic yards (cy). In addition, there may be other locations along the spillway that restrict fish passage and could be modified. Modifications may include excavation of lateral trenches for connectivity during low flows and excavation of resting pools for use during high flows. The estimated volume of rock excavation for such features is about 500 cy. The estimated total volume of rock excavation is 1,500 cy.

The rock excavation could be performed using a backhoe with hammer attachment, by drilling and blasting, or by some other method. To perform this work in the dry, it would be desirable to dewater the spillway by reviving the top row of outlet works pipes to pass flow from the North Fork Toutle River. This would involve excavating some sediment in front of the outlet pipes and using the excavated sediment to form a temporary berm to direct the river to the outlet pipes instead of the spillway. The work would be performed in the late summer when river flow is low. An alternative may be to divert the flow locally around the work areas in the spillway using temporary cofferdams. The total estimated cost for this measure is $300,000 (includes contingency, engineering and design, and construction supervision and administration).

Fish Ladder at Spillway. Another measure to improve upstream fish passage at the SRS would be to construct a fish ladder from the SRS tailwater to the headwaters above the SRS spillway. This measure was considered by the Corps at a 1987 interagency meeting. At that time, Corps engineers concluded that there were insurmountable technical difficulties. The difficulties, which remain today, include a lack of stable tailwater and headwater pools; an unreliable supply of auxiliary water or difficulties with sediment load in the water choking pipes; sediment buildup in the ladder itself; and difficult access for construction and maintenance. As a result, constructing a fish ladder at the SRS spillway was not considered a feasible method of passing fish upstream of the structure.

Figure 12. 1995 Erosion Creating the Falls

Figure 13. The Falls Today

8.1.2. Fish Collection Facility

Fix Existing FCF. According to the operators of the FCF, the primary problem affecting the facility is the sediment load and sediment accumulation in the facility. If the sediment could be kept out, the operators claim the facility would function adequately. Based on this assessment, the proposed fix involves minimizing the amount of sediment entering the facility. The fix involves three items: (1) reviving the 24-inch diameter sediment sluice; (2) removing the stoplog in the fish barrier; and (3) building a settling box at the water intake. These items are shown on Plate 1 (located at the end of this report).

Water enters the facility by passing through a trash rack with a 3-inch clear spacing and over a 15-foot-long weir at elevation 750 mean sea level at the water supply intake. Water moves through a 15-foot by 28-foot sediment settling box with a bottom sloping toward a 24-inch diameter sediment sluice pipe. Sediment is supposed to settle in the box and flush out through the sluice pipe, discharging past the fish barrier. The remaining flow passes over a weir at elevation 751 and into the FCF.

Revive Sediment Sluice Pipe. The sediment sluice pipe is not flushing sediment from the weir box, possibly because it is plugged with debris. The cause of the sediment sluice malfunction would be investigated. If the pipe is plugged with debris, one solution may be to clean out the pipe from the downstream end using a hydrojet. The total estimated cost of this work is $10,000.

Remove Stoplog. The fish barrier has a 2-foot-deep by 10-foot-wide notch adjacent to the facility and near the water intake (Plate 2). When open, water velocities through the notch are higher than over the rest of the barrier, which discourages the buildup of sediment near the notch and water intake. A stoplog is currently in place, effectively filling the notch so that water passes over the entire barrier evenly. Under this condition, sediment is more likely to build up near the water intake. It has been reported that the stoplog is jammed in place and cannot be removed easily. One solution is to mobilize a high-capacity crane to lift the stoplog out of the notch. Alternative methods of removing the stoplog also should be explored. The total estimated cost of this work is $5,000.

Settling Box. The existing sediment settling box may be too small to allow sufficient settling of sediment. The flow into the FCF ranges from 127 to 274 cfs for river flows at 170 to 5,000 cfs, respectively. The settling box needs to have a large enough detention time to allow particles of sediment to fall out as the flow passes through the box (i.e., the detention time should be greater than the fall time). Table 7 shows the results of simplified calculations of detention time and fall time in order to make an approximation of revising the size of the settling box. Plate 1 shows the revised size of the settling box, at 30 feet by 150 feet, instead of the existing 15 feet by 28 feet. The water intake, including trash rack and weir, would be moved upstream.

Table 7. Calculations of Detention Time and Fall Time for the Sediment Settling Box

Settling Box				Detention time for Q_{FCF} = 274 cfs (seconds)
Width (ft)	Length (ft)	Height (ft)	~ Volume (ft^3)	
30	150	7	31,500	115
Grain Size (fine sand; in mm)		Fall Velocity		Fall time for height = 7 ft (seconds)
		cm/s	ft/s	
0.4		5	0.16	43

274 cfs is flow through FCF when river flow is 5,000 cfs.
Fall velocity is for stagnant water. Hindered settling in moving water may reduce fall velocity.
ft = feet; ft^3 = cubic feet; mm = millimeters; cm/s = centimeters/second; ft/s = feet/second

The FCF currently collects roughly 10,000 cy of sediment per year (estimated from the amount of sediment the facility operators remove each year). The goal is to collect this sediment load in the resized settling box to prevent it from entering the facility. Sediment would be removed from the box by two mechanisms: flushing out through the sediment sluice and removal by use of vacuum pumping. The vacuum pumping system could involve an agitator to stir up the sediment from the bottom of the box and a pump designed to handle sediment with its suction line in the box and the discharge point at a nearby location with truck access. The total estimated cost of the resized settling box is $250,000. In addition to this initial cost, the estimated cost of removing and disposing of the sediment from the box is $50,000 annually.

New Trap-and-Haul FCF. A new trap-and-haul FCF could be constructed to more effectively move fish upstream of the SRS. One option would be a facility consisting of a fish ladder with auxiliary water leading to an elevated holding pool and a hands-off sorting structure that would load fish into trucks below. This type of facility is currently being designed for the Corps' Cougar Dam and Lake project in the McKenzie River watershed in Oregon. Based on the cost estimate for the Cougar Dam project, the total estimated cost of a new trap-and-haul facility just downstream of the SRS ranges from $10 to $15 million.

Remove FCF Fish/Velocity Barrier. If the SRS spillway improvements lead to desirable volitional fish passage, the next step could be to modify the FCF itself to allow for volitional passage. Volitional passage at the FCF is prevented by a concrete fish/velocity barrier (Figure 14). The barrier forms a two-tiered falls about 25 to 30 feet in height. To allow for volitional fish passage, the concrete structure would be removed and the upstream river channel would be graded to produce a navigable slope and channel for fish. The total estimated cost for this measure is $1 million.

Figure 14. FCF Fish/Velocity Barrier

Source: Steward and Associates

8.1.3. Release Sites

New Release Site above SRS (volitional movements). A new release site would be constructed just above the SRS on the south side. The existing road from the crest to the pool at the left abutment would be improved and extended to the new release site at the North Fork Toutle River. Work at the release site would involve building a corrugated metal pipe chute for delivering fish from a truck into the river, a gravel turnaround area, and possibly measures to stabilize the release site area. The estimated cost for this measure is $100,000.

Improve Tributary Sites. This work would be similar in scope to the new release site above the SRS but without the road work. The estimated cost to improve the four existing release sites is $200,000.

8.2. Confluence Connectivity/Fish Habitat

8.2.1. Sediment Plain Structures

Pile Dikes. Pile dikes may potentially be effective for concentrating a braided river with high sediment load into a single channel. Pile dikes may be constructed in various ways. For cost estimating purposes, the proposed pile dike is considered to be constructed using timber piles spaced 2.5 feet apart and connected with a horizontal spreader timber. Further assessment of pile dikes and the true potential of effectively using them in this dynamic environment will be required during the feasibility phase.

The proposed location for a pile dike structure is in the vicinity of Alder Creek (Figure 15). The North Fork Toutle River currently passes between the two “islands” in the sediment plain. In the past the North Fork has passed on the east side of the larger, more northerly island. The pile dike would span roughly 0.5 mile from the northeast side of the sediment plain to the southern tip of the larger island, guiding the North Fork to stay in its current location west of the larger island. It is expected that sediment would accumulate around the pile dike during high flow events; after high flow events the river would recede into the single channel.

Because the sediment plain is still filling, it is anticipated that a second pile dike may be needed at a later date, possibly in 15 years. Figure 16 shows the sediment plain's profile upstream of the SRS from 1988 to 2004. The original estimate of the approximate final slope was one-half the original stream slope. This slope is shown on Figure 16 as S/2. If the sediment plain continues to fill to S/2, the range of future deposition is from 0 to approximately 40 feet in height. Figure 17 shows deposition from 3 to 7 feet in the vicinity of Alder Creek from 2001 to 2004. Note the slope of the plain from east to west. The proposed pile dike would maintain this slope. However, after sediment has filled to near the top of the pile dike on the east side of the plain, further deposition may tend to migrate west, decreasing the slope from east to west and increasing the chance of an avulsion causing the river to shift east of the island. To reduce the likelihood of this occurring, a second pile dike would be constructed above the first when/if the ground on the west side builds to an elevation near the top of the first dike (Figure 17). This series of two successive dikes would maintain a significant elevation gradient across the plain (high to low from east to west) and maintain a barrier to an avulsion as the sediment plain fills. The estimated cost of the pile dike measure is $900,000 (includes contingency, engineering and design, and construction supervision/administration). A similar cost would be required if a second pile dike is needed, possibly in 15 years.

In addition to pile dikes, other types of sediment plain structures were considered but ultimately removed from the list of potential measures. Several types of low-height sluicing structures were considered including gabions, logs, large stones, jersey barriers, sheet piling, and a modified high density polyethylene (HDPE) net pen structure envisioned by a local resident and engineer, Lou Reebs. A low-height sluicing structure would act similarly to a pile dike, trapping sediment during high flow events and guiding low flows to a desirable established channel, but would be lower in height than a pile dike. Because of the lesser height of the sluicing structures, more of them would be needed to keep up with the rise in the sediment plain and as a result, the low-height sluicing structure options turned out more expensive than the pile dikes option.

A large embankment-type structure with spillway also was considered. The structure would be located upstream of the N1 structure and would be $^{1}/_{8}$ to ½ of the size of the N1 structure. The purpose of this structure would be to retain sediment continuing to erode from the debris avalanche. Because of the high cost of such a structure and the high probability of it breaching, as N1 breached, this type of structure was not considered further.

8.2.2. Tributary Plantings/Stabilization

Treatments include planting riparian vegetation, introducing woody debris, and stabilizing creek banks, if necessary. The purpose of this work would be to maintain and enhance habitat. The Alder, Deer, Hoffstadt, and Bear tributaries may benefit from planting/stabilization work. The total estimated initial cost to treat all four tributaries is $800,000 including contingency, engineering and design, and construction supervision and administration. The construction cost is based on treating 500 ft of tributary, for four tributaries, at a cost of $300 per linear foot. The cost to maintain plantings and stability under changing conditions is $250,000 every 5 years.

Figure 15. Proposed Location of Pile Dike

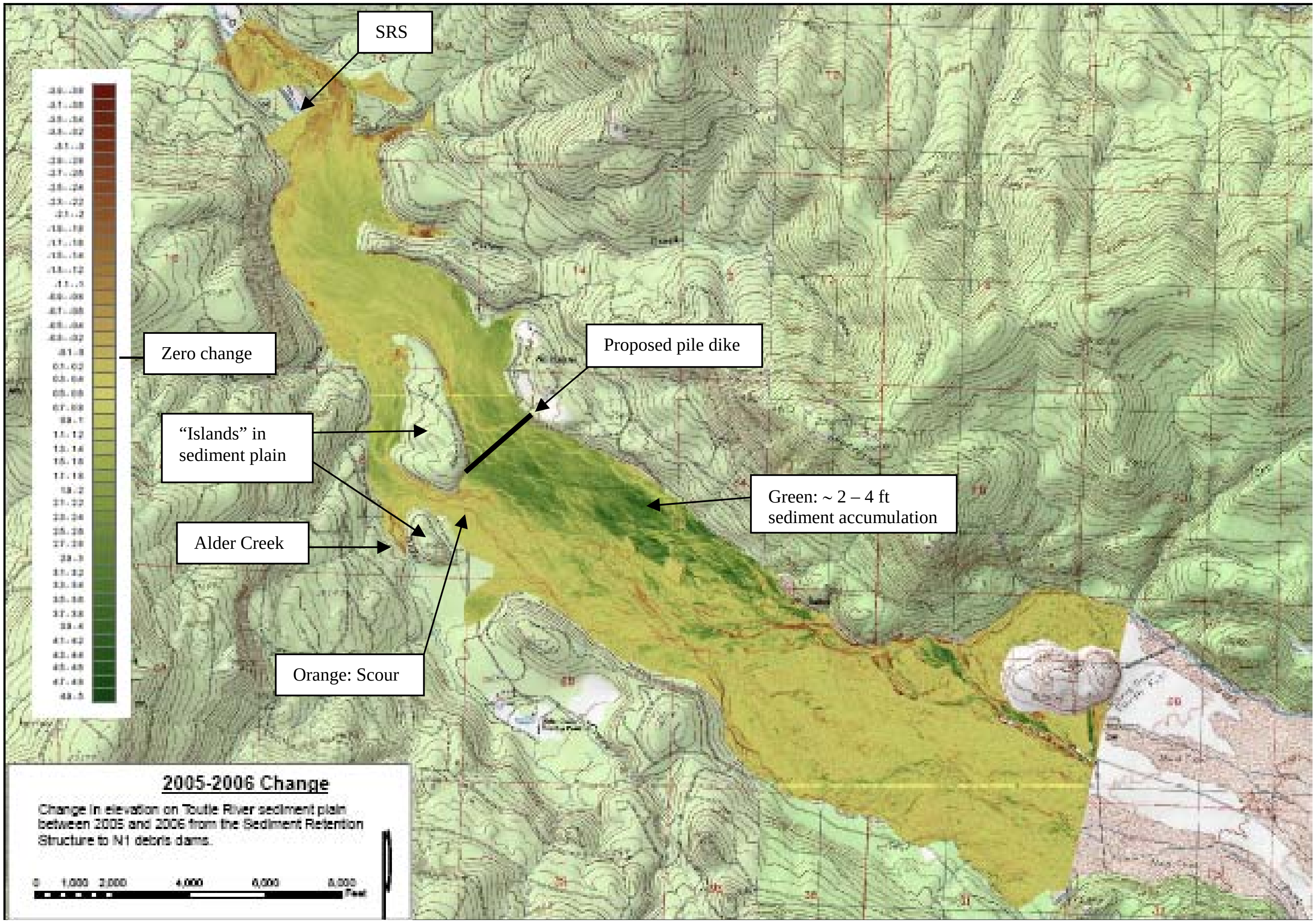


Figure 16. Sediment Profile Upstream of the SRS

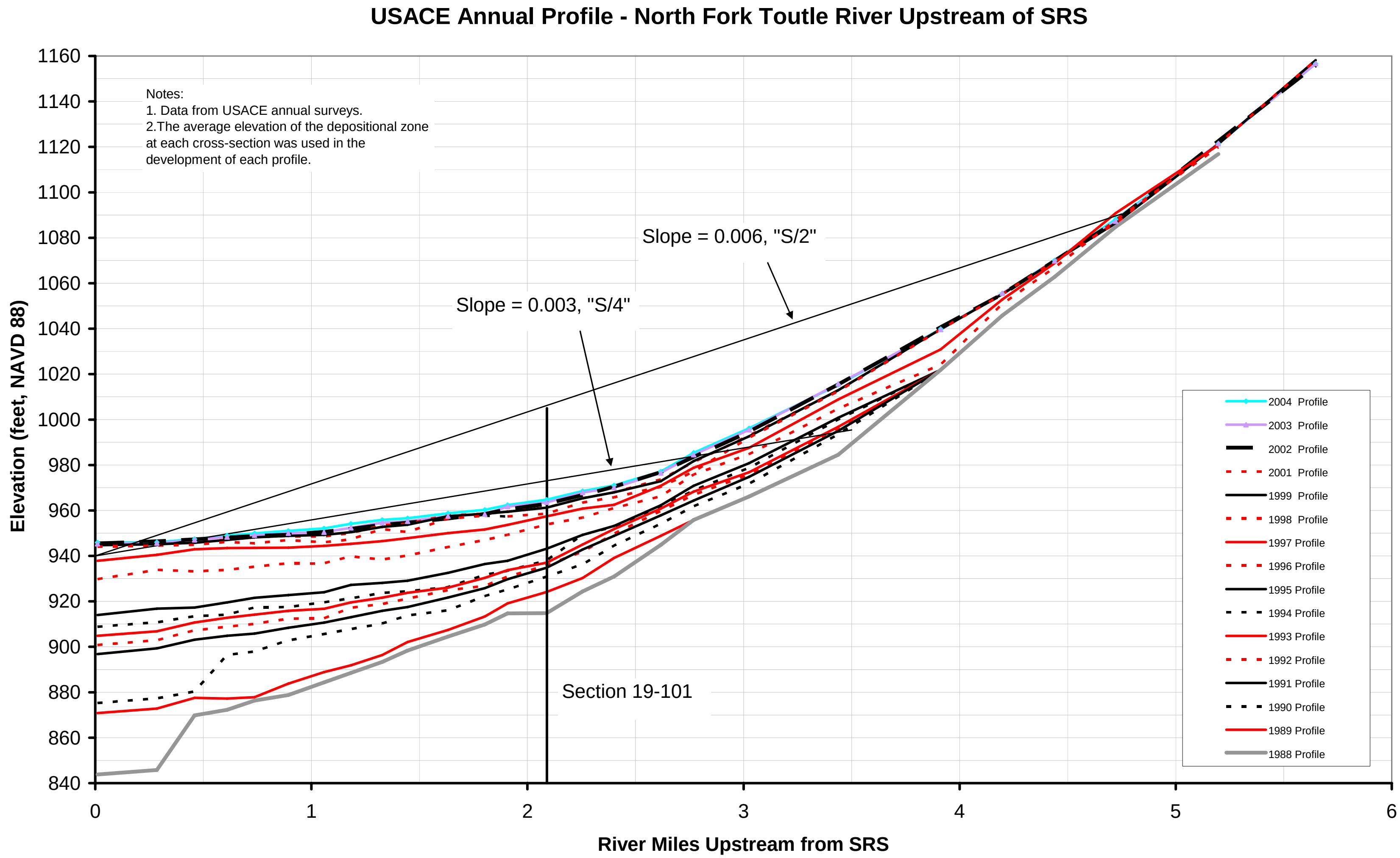
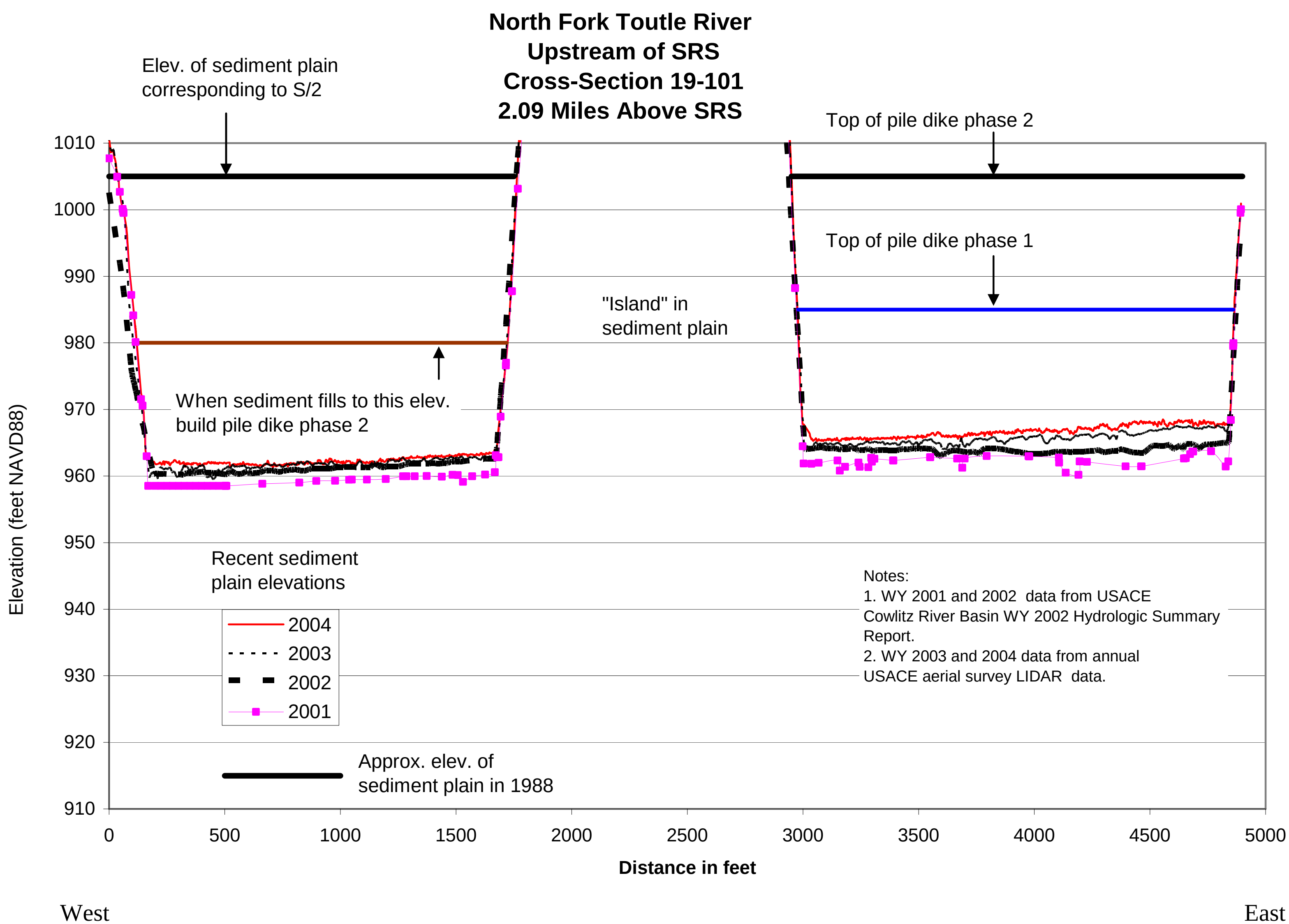


Figure 17. Sediment Plain Cross Section Two Miles above the SRS near Alder Creek



8.2.3. Toutle River Off-channel Habitat Restoration Downstream of SRS

Preliminary work to identify potential opportunities to create off-channel habitat was initiated by Tetra Tech (2006). In the preliminary work, 14 projects along the lower Cowlitz River involving restoration of side or off-channel areas to create fish habitat for a variety of fish species were identified. Activities include reconnecting side and off-channels to the Cowlitz by excavation, placement of large woody debris and log jams, riparian plantings, and bioengineered bank stabilization. The proposed projects range in size from 8 to 70 acres. The number of off-channel restoration projects proposed along the Toutle River between the SRS and the Cowlitz River in this report depends on the magnitude of benefit for fish per project. The total estimated cost of each project is $2 to $2.5 million.

9. ENVIRONMENTAL BENEFITS OF POTENTIAL MEASURES

The determination of environmental benefits of the alternative measures was based on three primary components:

- The percent of fish that successfully pass above the SRS with a given alternative.
- The effects of the trap-and-haul program on fish that successfully pass above the SRS (represented as percent of fish that are negatively affected by the operations).
- The effect of episodic high sediment loads on the successful return of adult fish.

Estimates for both steelhead and coho were made separately and the values were averaged for an overall percentage and compared against the baseline estimate of the current situation to come up with an environmental output improvement for a given alternative. There is a large amount of uncertainty and variability around these estimates as data is limited but every effort was made to ensure that the values were treated consistently.

For alternatives that involve the use of the FCF, the first component of the environmental outputs is an estimate of the trap efficiency for fish (TE). This is an estimate of the number of fish that reach the trap on their way to streams above the SRS that are successfully captured by the trap. Many factors affect this estimate, primary of which is the ability of migrating fish to find the entrance to and remain in the trap. Level of flow, in-river sediment load, the operational condition of the trap, and how well fish are collected from the trap will affect the TE. Few data of trapping efficiency are available, so a range of estimates for year-to-year TE was based on discussions with biologist operating the facility and by comparing the design and operation of the North Fork Toutle FCF with other traps in the region. Relatively speaking, high flow and sediment load event years, such as occurred in the fall of 2006 will greatly reduce the TE, especially with the long-term operational, maintenance, and effects from potential design problems that have been ongoing.

For alternatives that do not include the FCF, estimates for the first component of the environmental outputs are based on the percentage of fish that successfully pass up the spillway channel (PE = passage efficiency). Preliminary data from a small sample of radio-tagged steelhead and coho show that about 20% of steelhead and no coho ascend the existing SRS spillway. Coho do not appear able to navigate the existing falls at the bottom of the spillway. Estimates of PE with modifications made at the spillway are based on the expected flow velocity changes, the increase in connectivity, and the distribution of resting pools that would be engineered into those modifications; the swimming capabilities of steelhead and coho; and how well these species pass streams with similar conditions to those expected at the modified spillway. The PE estimates (60% to 80% for steelhead and 50% to

70% for coho, depending on environmental conditions) would need to be verified by evaluations of radio-tagged fish to ensure expected levels of passage are being achieved.

The second component of the environmental outputs consists of an estimate of the change from the existing to an alternative trap-and-haul program on those fish that are trucked above the SRS. This estimate is based on changes to the quality of the trapping and handling operations, improvements to the release sites, and expected changes to the historic data on the level of successful production of juveniles in streams where trap-and-haul fish are released. Some alternatives do not include trap-and-haul operations and thus, do not include a value for this component.

The third component is an estimate of the potential effects of modifications made above the SRS to direct flows and stabilize channels with the idea of improving sediment loads, water temperatures, and connectivity over the passage season. The estimate is in terms of how these modifications alter the percentage of fish successfully returning above the SRS. Naturally occurring revegetation along the North Fork Toutle tributaries (above the periodic high flow events that occur along the mainstem) have greatly improved spawning by reducing temperatures and stabilizing streambeds. However, there is considerable uncertainty as to whether the proposed alternative addressing this third component (pile diking and vegetation planting within the periodic high flow event zone) would actually reduce sediment loads or maintain connectivity if implemented, especially after observing the effects of the major flow event in November 2006. In addition, the effects to spawning beds and backwater connectivity in areas downstream from the SRS and FCF from deposition of high sediment loads may impact fish outside of the focus of this report.

The majority of the negative effects associated with high sediment loads and temperatures are expected to impact outmigrating juveniles. Studies in 2001 and 2002 evaluated the cumulative effects of passage through the spillway and FCF on juvenile salmonids. Transport, handling, and passage of hatchery coho smolts released through the spillway or over the FCF dam downstream did not appear to affect short-term survival. Although around 22% of the smolts showed some signs of injuries passing through the spillway and FCF, nearly all of the injuries were superficial dorsal scrapes that healed quickly and did not effect survival for the 160 days they were held post-treatment (personal communication, Craig Olds, 2002).

The baseline value of the existing trap-and-haul program was determined by using the same rationale as discussed above. Trap efficiency varies greatly at the current trap and it was essential to address that variability in determining a baseline output over the year for the two fish species. High flow and sediment condition years, maintenance and operational problems, and design limits can greatly reduce the number of fish entering the trap. Estimates for these values were based on discussions with biologists operating the trap, and comparing the operation and maintenance of this facility to other documented facilities. The estimates ranged from 45% to 68% TE for steelhead and 38% to 56% TE for coho depending on environmental and facility conditions. The high debris- and sediment-filled flows that occurred in November 2006 and the lasting effects from this event further limited the capabilities of the existing trap; this was considered to have reduced the existing baseline toward the lower third of the above TE ranges. The estimate of TE for fixing the current FCF was 60% to 80% and 90% for a new state-of-the-art FCF for both species based on trapping success at new facilities in the region.

Additional trap-and-haul program factors also entered in to determining the baseline value when considering the second component listed above. Several practices used at the FCF are less than optimal for a trap-and-haul program. Fish are hand-netted from a non-functioning crowder pool where they can reside for up to 5 days before capture, lifted over a fence, and carried in nets to an examination table before being placed in the transport truck. Several of the release sites have difficulties being reached when conditions are wet; many of the release pipes have limited water, variable slopes, rough joints between pipe sections, and do not drop fish into pools. The Hoffstadt Creek release site for steelhead is located above a natural barrier in a stretch of stream where native spawning cutthroat have been displaced. Adult fish counts and juvenile production estimates for steelhead and coho in Hoffstadt Creek made by Weyerhaeuser from 1991 (when juvenile stocking of coho ceased) to 2004 found a steady positive correlation between steelhead spawners and juveniles although coho production remained very, very low even with increased releases of coho over the years. This seems to indicate that either coho are spawning unsuccessfully or they are leaving Hoffstadt Creek, perhaps in search of their natal streams. The negative effects from these factors related to the existing trap-and-haul program were estimated at (-15%) for steelhead and (-30%) for coho. The negative value of the trap-and-haul effects would drop if the FCF was repaired, if a new FCF was built, if a new release site was built, or if an existing tributary release site were improved.

One factor not included in the environmental outputs is the risk related to a major volcanic or seismic event occurring on Mount St. Helens. It is impossible to predict the probability of such an event within the 30-year time frame of this study. However, any sizeable debris flow event would likely devastate any measures constructed within the sediment plain.

Lastly, not all actions that make up an alternative are additive and some actions cannot stand alone. For instance, making spillway repairs to allow good volitional passage must also include either improvements to the FCF or removal of the FCF. Also, when a range of values for the two fish species was derived, an average of these values was used for the net increase.

Table 8 summarizes the estimated environmental outputs for the range of potential ecosystem restoration alternatives considered. Without improvements, it is estimated that the existing trap-and-haul operations provide about 42% to 64% transport/passage for steelhead and 35% to 53% transport/passage for coho. All other improvements are compared to this without-project condition to determine what kind of increase in outputs various options can provide.

Table 8. Environmental Outputs by Potential Ecosystem Restoration Alternative

Alternatives	Fish Species	Output Assumptions *	Output	Midpoint % Output	Increase Above Baseline	Average % Increase (Units)
BASELINE (existing trap & haul)	Steelhead	Currently in low range of TE and 15% T&H effect with 3% sed. effect	42% - 64%	0.48	---	---
	Coho	Currently in low range of TE and 30% T&H effect with 3% sed. effect	35% - 53%	0.40 [0.44 mean for both fish]	---	
IMPROVE FALLS/SPILLWAY and FIX FCF	Steelhead	60% - 80% TE/PE, 5% T&H effect, 3% sed. effect	54% - 73%	0.635	0.155	15.5
	Coho	50% - 80% TE/PE, 10% T&H effect, 3% sed. effect	42% - 69%	0.555	0.155	
IMPROVE FALLS/SPILLWAY and FIX FCF + PILE DIKES	Steelhead	60% - 80% TE/PE, 5% T&H effect, 1% sed. effect	56% - 75%	0.655	0.175	17.5
	Coho	50% - 80% TE/PE, 10% T&H effect, 1% sed. effect	44% - 71%	0.575	0.175	
IMPROVE FALLS/SPILLWAY + REMOVE FCF BARRIER	Steelhead	60% - 80% PE, 3% sed. effect	57% - 77%	0.67	0.19	20.5
	Coho	50% - 80% PE, 3% sed. effect	47% - 77%	0.62	0.22	
IMPROVE FALLS/SPILLWAY + REMOVE FCF BARRIER + PILE DIKES	Steelhead	60% - 80% PE, 1% sed. effect	59% - 79%	0.69	0.21	23.0
	Coho	50% - 80% PE, 1% sed. effect	49% - 79%	0.64	0.24	
FISH LADDER AT SPILLWAY	not feasible	---	---	---	---	---
FIX EXISTING FCF	Steelhead	60% - 80% TE, 10% T&H effect, 3% sed. effect	51% - 70%	0.605	0.125	11.5
	Coho	60% - 80% TE, 25% T&H effect, 3% sed. effect	43% - 58%	0.505	0.105	
FIX FCF + NEW RELEASE SITE	Steelhead	60% - 80% TE, 5% T&H effect, 3% sed. effect	54% - 73%	0.635	0.155	18.0
	Coho	60% - 80% TE, 10% T&H effect, 3% sed. effect	51% - 70%	0.605	0.205	
FIX FCF + NEW RELEASE SITE + PILE DIKES	Steelhead	60% - 80% TE, 5% T&H effect, 1% sed. effect	56% - 75%	0.645	0.165	19.0
	Coho	60% - 80% TE, 10% T&H effect, 1% sed. effect	53% - 71%	0.62	0.22	
FIX FCF + IMPROVE TRIBUTARY SITES	Steelhead	60% - 80% TE, 10% T&H effect, 3% sed. effect	51% - 70%	0.595	0.115	14.0
	Coho	60% - 80% TE, 15% T&H effect, 3% sed. effect	48% - 65%	0.565	0.165	

* Notes:
TE = trap efficiency for fish
T&H = trap-and-haul
PE = passage efficiency
sed. effect = sedimentation effect

Table 8 (continued). Environmental Outputs by Potential Ecosystem Restoration Alternative

Alternatives	Fish Species	Output Assumptions *	Output	Midpoint % Output	Increase Above Baseline	Average % Increase (Units)
FIX FCF + IMPROVE TRIBUTARY SITES + PILE DIKES	Steelhead	60% - 80% TE, 10% T&H effect, 1% sed. effect	53% - 71%	0.61	0.13	16.0
	Coho	60% - 80% TE, 15% T&H effect, 1% sed. effect	50% - 67%	0.585	0.185	
NEW FCF (state-of-the-art)	Steelhead	90% TE, 10% T&H effect, 3% sed. effect	78%	0.78	0.30	30.0
	Coho	90% TE, 20% T&H effect, 3% sed. effect	70%	0.70	0.30	
NEW FCF + NEW RELEASE SITE	Steelhead	90% TE, 5% T&H effect, 3% sed. effect	83%	0.83	0.35	37.0
	Coho	90% TE, 10% T&H effect, 3% sed. effect	78%	0.78	0.38	
NEW FCF + NEW RELEASE SITE + PILE DIKES	Steelhead	90% TE, 5% T&H effect, 1% sed. effect	85%	0.85	0.37	39.0
	Coho	90% TE, 10% T&H effect, 1% sed. effect	80%	0.80	0.40	
NEW FCF + IMPROVE TRIBUTARY SITES	Steelhead	90% TE, 10% T&H effect, 3% sed. effect	78%	0.78	0.30	32.0
	Coho	90% TE, 15% T&H effect, 3% sed. effect	74%	0.74	0.34	
NEW FCF + IMPROVE TRIBUTARY SITES + PILE DIKES	Steelhead	90% TE, 10% T&H effect, 1% sed. effect	80%	0.80	0.32	34.0
	Coho	90% TE, 15% T&H effect, 1% sed. effect	76%	0.76	0.36	
NEW RELEASE SITE	---	Results same as baseline but with 10% improvement to T&H effects so benefits = 10%		---	---	10.0
IMPROVE TRIBUTARY SITES	---	Results same as baseline but with 5% improvement to T&H effects so benefits = 5%		---	---	5.0
PLANTINGS @CONFLUENCES & OFF-CHANNEL BACKWATER HABITAT (Toutle River below SRS)	---	Outputs not quantified	---	---	---	---

* Notes:

TE = trap efficiency for fish
T&H = trap-and-haul
PE = passage efficiency
sed. effect = sedimentation effect

10. CONCLUSIONS

Table 9 summarizes the net increase in outputs, total estimated costs, relative cost per output, and the ranking order for each potential ecosystem restoration alternative. Based on this preliminary analysis it appears there are several potential combinations of restoration measures to consider for implementation. The No Action alternative (baseline, existing trap-and-haul operation) provides existing levels of output (about 44%) at no increased cost. Based on the cost estimates and output estimates, it appears that after the No Action alternative, the best investment based on relative cost per output is the new release site. After that, improving tributary sites or improving the SRS spillway and removing the FCF barrier are the lowest cost per output. There is a significant breakpoint where costs per output increase when the cost of constructing a new FCF is added to the mix.

Table 9. Ranking of Potential Ecosystem Restoration Alternatives

Alternative	Net Increase in Outputs	Total Estimated Cost ($) (not annualized)	Relative Cost/Output ($)	Rank
BASELINE/NO ACTION (existing trap & haul after Nov 2006 high water event) = 44%	---	---	---	---
IMPROVE FALLS/SPILLWAY + FIX FCF	15.5	2,315,000	149,355	5
IMPROVE FALLS/SPILLWAY + FIX FCF + PILE DIKES	17.5	4,115,000	235,143	10
IMPROVE FALLS/SPILLWAY + REMOVE FCF BARRIER	20.5	1,700,000	82,927	3
IMPROVE FALLS/SPILLWAY + REMOVE FCF BARRIER + PILE DIKES	23.0	3,500,000	152,174	6
FISH LADDER AT SPILLWAY	not feasible	not feasible	not feasible	---
FIX EXISTING FCF	11.5	2,015,000	175,217	8
FIX FCF + NEW RELEASE SITE	18.0	2,115,000	117,500	4
FIX FCF + NEW RELEASE SITE + PILE DIKES	19.0	3,915,000	206,316	9
FIX FCF + IMPROVE TRIBUTARY SITES	14.0	2,215,000	158,214	7
FIX FCF + IMPROVE TRIBUTARY SITES + PILE DIKES	16.0	4,015,000	250,938	11
NEW FCF	30.0	12,900,000	430,000	15
NEW FCF + NEW RELEASE SITE	37.0	13,000,000	351,400	12
NEW FCF + NEW RELEASE SITE + PILE DIKES	39.0	14,800,000	379,500	13
NEW FCF + IMPROVE TRIBUTARY SITES	32.0	13,100,000	409,375	14
NEW FCF + IMPROVE TRIBUTARY SITES + PILE DIKES	34.0	14,900,000	438,235	16
NEW RELEASE SITE (can be stand alone if current FCF can function as it did pre-Nov 2006)	10.0	300,000	30,000	1
IMPROVE TRIBUTARY SITES (can be stand alone if current FCF can function as it did pre-Nov 2006)	5.0	400,000	80,000	2
PLANTINGS AT CONFLUENCES	---	2,050,000	---	---
OFF-CHANNEL BACKWATER HABITAT (Toutle River below SRS)	---	2,250,000	---	---

11. POTENTIAL ISSUES

11.1. Authority to Make Changes to Existing Corps Facilities for Restoration Purpose

Components of the proposed ecosystem restoration actions identified in the reconnaissance-level study would require changes to existing Corps facilities. Specifically, the SRS was constructed by the Corps to provide flood protection to the communities in the lower Cowlitz River. Proposed ecosystem restoration measures includes modifying the SRS spillway to allow upstream fish passage. This raises the question as to whether ecosystem restoration work at the SRS is possible under the original authorizing language. There is no explicit authorization language that mentions ecosystem restoration work other than mitigation for the SRS. However, historical documents and correspondence indicate modifications for fish passage were under consideration.

Based on a review of historical documents the following findings were made:

- Modifications at the SRS to benefit fish are appropriate under the original authority. Consideration of fish passage was incorporated in the design of the SRS spillway. Downstream passage through the spillway was intended once sediment filled behind the structure. The Corps anticipated fish passage would be possible upstream at some point in the future; and necessary modifications to allow that are warranted.
- The original spillway was designed to provide for downstream and upstream fish passage. Therefore, the original authority could be used to modify facilities to provide fish passage.
- The reviewed documents do not explicitly mention potential future modifications to fish and wildlife measures under the original project authority. The Local Cooperative Agreement explicitly indicates the State of Washington is responsible for operating and maintaining the FCF that was constructed by the Corps – there was no mention of additional measures or modifications that could/would be considered at a later date. However, a 1998 Corps' planning letter report explicitly mentions upstream fish passage improvements at the SRS may be warranted to "complete the project."
- Internal Corps' correspondence indicates upstream fish passage modifications should be evaluated once sediment fills to the spillway elevation.

Based on a review and assessment of historical records, it may be possible for the Corps to evaluate and implement modifications at the SRS for fish passage under current authority. However, policy and legal issues remain and the Corps will need to resolve these issues before proceeding with any fish passage modification assessments at the spillway. Even if it is determined that the Corps can address fish passage issues at the SRS under existing authority, agreement from the WDFW on modifying/removing the FCF barrier must first occur.

11.2. Non-federal Sponsor

This reconnaissance study constitutes the first phase of study to define problems and opportunities, identify potential solutions, determine if there is federal interest, and determine if there is a non-federal sponsor willing to cost-share the feasibility study and implementation of a project. The reconnaissance phase is completed upon signing a Feasibility Cost-Sharing Agreement by the Corps and the non-federal sponsor. The second phase is completion of a feasibility study to optimize the plan to be built and it can take up to 3 to 5 years to complete. The feasibility study is cost shared equally between the Corps and the non-federal sponsor. The non-federal sponsor's share of construction costs is 35% and there is no limit to the federal share.

Feasibility level General Investigation studies for environmental restoration are authorized under Section 306 of the Water Resources Development Act of 1990, as amended. They involve jointly conducting a study with a non-federal sponsor and, if shown by the study to be feasible, the construction of the project.

11.3. Impact of Historical Agreements and Responsibilities

Provided below is a summary of pertinent information from the review of historical agreements/documents that may impact the viability of some of the proposed restoration actions.

<u>Local Cooperation Agreement between the Department of Army and State of Washington and Diking Improvement Districts (April 26th, 1986).</u>

> The Corps will perform the construction of the SRS, the fish mitigation measures at the SRS, the downstream dredging, and improvements to downstream levees. In addition, the Corps will operate and maintain the SRS itself. The State will operate and maintain all project mitigation measures, as well as the dredged material disposal sites. The State will operate and maintain the accumulated sediment behind the SRS and responsible to operate and maintain the fish facility.

<u>Letter from State of Washington, Department of Community Development to Corps of Engineers (May 3rd, 1993).</u>

> This letter indicates the ownership of the fish collection facility was turned over and accepted by the State of Washington. Specifically, the Department of (Fish &) Wildlife will be responsible for operating and maintaining the facility.

<u>Letter from Corps to Washington Department of Community Development (September 13th, 1989).</u>

> This letter indicates that with the transfer of the fish facility, the Corps does not intend to “experiment” with the design of this facility, and the Corps does not have authorization or funding for future work and, therefore, can make no further commitment.

<u>Sediment Retention Structure, Fish Collection Facility Design Memorandum No. 10, Mount St. Helens Sediment Control Cowlitz, and Toutle Rivers, Washington (September 1987).</u>

> Discussion refers to downstream migrants at SRS and some concerns about the design. Discussion is included indicating that NMFS had concerns with design of downstream fish passage through the SRS. An attached letter emphasizes that the Corps will design and construct facilities and it will be responsibility of State of Washington to operate and manage facilities. Reference is made to the Local Cooperative Agreement. The FCF is described as permanent feature.

<u>Mount St. Helens, Washington Decision Document (October 1985).</u>

> Specific reference to mitigation measures for SRS, levees and dredging. Mitigation for SRS is fish bypass facility to trap adults to be hauled upstream of SRS. Juveniles would pass downstream through outlet works (until closed) and then the spillway. The mitigation and monitoring requirements discussed.

1998 Corps Planning Letter Report (June 1998).

The Planning Letter indicates there was some thought and consideration of upstream fish passage through the SRS spillway. It is stated that an evaluation needs to be completed to determine the extent of design and construction required….for modifications to the spillway so that upstream migrating adults could safely pass the SRS. Adult passage using the spillway would require less human handling and provide a more natural condition with less stress to the fish than that which occurs through operation of currently existing FCF with its trap and haul operations.

The report conclusions mention that on-going coordination will be required to evaluate the justification within the existing legislation for upstream fish passage at specific locations. These studies should be viewed as actions to complete the previously uncompleted portions of the originally authorized project. Therefore, it is appropriate to fund these actions through the existing Construction General authority.

Internal E-mail (Christensen) to other internal Corps staff (January10, 1996).

The e-mail stated that an analysis of eventual upstream fish passage through the spillway and the natural erosion gullies should be considered, unless more sediment is being transported than we predicted or the decision is made to increase the available storage behind the structure, both of which were to be evaluated as the pool began to reach full capacity.

The previously established agreements with multiple responsible parties in the Mount St. Helens project area makes it necessary to clarify roles and responsibilities for the proposed restoration actions. For instance, the WDFW is responsible for the operation and maintenance of the FCF located downstream of the SRS. Any successful plan to improve upstream fish passage will be contingent upon the participation of the State of Washington in either modifying or removing the existing FCF.

11.4. Interrelationship of the Previous Work and Proposed Restoration Activities

The implementation of any restoration plan must be fully integrated and coordinated with the need to maintain flood protection levels for communities along the Lower Cowlitz River. Specifically, the Corps is responsible for the ongoing sediment monitoring and analyses work in the basin to maintain long-term flood protection in levels the Lower Cowlitz River through 2035.

11.5. Land Ownership

The location of potential ecosystem restoration actions will likely encompass multiple ownerships and will require a collaborative effort in order to successfully implement ecosystem restoration. For instance, the Corps has ownership of the SRS structure itself but the sediment pool behind the dam is under ownership of the State of Washington. The FCF is owned and operated by the State of Washington. The tributaries above the SRS are primarily located on Weyerhaeuser property. In addition, the U.S. Forest Service manages significant amounts of land in the upper Toutle watershed.

12. NEXT STEPS

Following are specific steps that will need to be completed in order to move forward with the feasibility phase:

1. Determine non-federal sponsorship.
2. Develop Feasibility Cost Sharing Agreement (FCSA) between the Corps and non-federal sponsor for a feasibility-level study.
3. Before proceeding with feasibility study obtain necessary interagency agreements. This would include:
    a. An agreement from the State of Washington that modifications to, or removal of, the existing FCF are acceptable.
    b. A determination that volitional passage of wild and hatchery fish is acceptable to the fish agencies.
    c. A determination of whether or not it is within the existing Corps' authority to modify the SRS spillway for upstream volitional fish passage.
4. Determine what actions can be implemented under the existing Corps authority and before feasibility study is complete. Potential actions to consider include modifications to the SRS and the FCF.
5. Conduct the feasibility-level study and determine a recommended ecosystem restoration plan for implementation.
6. Develop a Project Cooperation Agreement (PCA) with the non-federal sponsor.
7. The recommended ecosystem restoration plan will be shared with the Office of Management and Budget and submitted to Congress for approval.
8. Complete plans and specifications for the recommended ecosystem restoration plan.
9. Construct the ecosystem restoration plan.

13. RECOMMENDATION

The General Reevaluation Study Reconnaissance Report for the Mount St. Helens Project identified a range of possible alternatives that could provide benefits to anadromous fish species in the Toutle River watershed that are currently listed as threatened under the Endangered Species Act. Based on this preliminary assessment, a federal interest was established to pursue upstream fish passage improvements and ecosystem restoration measures in the Toutle River watershed.

However, there are inherent risks and uncertainties that will need to be considered. Further study may identify reasons that preclude the implementation of fish passage improvements identified in the General Reevaluation Study Reconnaissance Report. Erosion and sediment movement into the North Fork Toutle River drainage continues to be significant and unpredictable. Consequently, there is a risk associated with investing in ecosystem restoration measures for the Mount St. Helens Project due to the instability of the North Fork Toutle River drainage and continuing sedimentation effects caused by the 1980 eruption of Mount St. Helens. It is anticipated that all ecosystem restoration work will focus on near-term actions to sustain and improve access to the tributary habitat above the sediment retention structure located at river mile 13.2 of the North Fork Toutle River. In the future, the North Fork Toutle River system may become stable enough to consider a broader range of ecosystem restoration measures.

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US Army Corps
of Engineers ®
Portland District

Mount St. Helens Ecosystem Restoration General Reevaluation Study Reconnaissance Report

Appendix A

Additional Study Information

Mount St. Helens Sediment Management and Ecosystem Restoration 1
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July 2007

Mount St. Helens Sediment Management and Ecosystem Restoration

September 22, 2005
12:00 to 1:30 PM
Woodland, WA

1. Discuss Issues Raised by Mr. Lou Reebs
   a. Long Term SRS capacity in relation to downstream sediment deposition
   b. Stabilizing sediment upstream of remaining portions of N1 structure
   c. Alternative sediment stabilization options
   d. Additional data sources available
   e. Other
2. Local efforts relating to ecosystem restoration
3. Current restoration research activities
4. Other

Meeting Notes

Theme of Discussion: There are communication issues and the time it takes Corps to complete analyses.

1. First portion of meeting Lou Reebs discussed his concerns/reactions to our responses to his letters.
   a. Statements we made about downstream fish and damage to them not true—Some documents indicate early on there were problems that have been addressed. Monitoring continues?
   b. According to the 2002 reanalysis report total storage possible at SRS has been adjusted downward from original analysis of 250 mcy storage to 174 mcy. Lou says all future documents should reflect this change.
   c. The SRS trap efficiency that was originally estimated (5 to 1) is not representative now that spillway is operable. Recent data showing 50% passing more representative to Lou.
   d. Lou doesn't believe the 3 phases of sediment trapping at SRS that Corps developed at the time SRS was planned.

2. Lou says there are many ways to be control sediment that the Corps is not implementing. Some that were mentioned:
   a. Modify Lovett (sp?) flow channel to reduce scouring events.
   b. Stabilize channel above N1 structure.
   c. Create island in pool behind SRS so that two channels are created that link to good spawning tributaries upstream.
3. Corps team needs to develop detailed plan for FY06 describing work to be completed and when.
4. Need to develop a more effective way to include local interests in tracking Corps progress. It was suggested a workshop could be held to lay out the different objectives of the interest groups and clarify what the Corps currently is working on, what Corps cannot currently do because of authority funding limitations but is striving to find ways to participate, and what activities the Corps will likely not participate. It was also suggested to hold more regular

meetings and involve technical experts. These meetings would be informal and focus on one or two specific activities and include the parties most interested in those subjects.

5. Group was pleased the Corps was participating in fish monitoring—A good first start. The Corps needs to continue to explore opportunities to participate in restoration activities through GRR, LCRER, CAP, PAS.
6. Miscellaneous:
    a. The COL would like to meet with PDT team again to discuss these issues. Include Martin Hudson.
    b. Get/review Craig Olds report on fish survival.
    c. Verify RE ownership of fish trap and that it was turned over to WDFW to operate and maintain.
    d. Identify/share known data on smelt.
    e. Verify PAS funding for monitoring has been provided.

Mount St. Helens General Reevaluation Report Study Workshop

Sponsored by the U.S. Army Corps of Engineers
and the Mount St. Helens Citizens Advisory Committee

February 13, 2006 Meeting Notes
Cowlitz Indian Tribe Administration Center

List of Participants – See attached list of participants

Agenda – See attached agenda

Summary of Meeting – Three items were discussed during the first half of the meeting. The subjects were:

1. A summary of the history of Corps involvement in the Cowlitz/Toutle watershed.
2. A review of ongoing Corps sediment management activities required to ensure flood protection in the lower Cowlitz.
3. Overview of the Corps planning process for evaluating ecosystem restoration opportunities.

The second half of the meeting was spent discussing potential issues surrounding the ecosystem restoration study, specifically the Reconnaissance study phase. A summary of the ideas expressed during that discussion follows, and is organized in three categories: existing data, issues, and potential actions.

<u>Existing Data (existing, potential and needed)</u>

- Ongoing radio telemetry study of adult coho salmon and steelhead at/above the SRS. Current data is limited. Preliminary results indicate coho can't ascend SRS. Some of the coho released at top of SRS spillway were able to navigate through sediments and were able to move into/stay in tributaries to spawn. Steelhead radiotracking just beginning.
- Funding for additional radio telemetry next year is very limited. This type of data is critical in order to develop a viable ecosystem restoration implementation plan.
- Smelt run research may be available from work done for Columbia River channel improvement project.
- Ongoing Washington Department of Fish and Wildlife studies (contact Wolf Dammers): (1) Spawning ground surveys, SF Toutle and Green River; (2) Fish passage above SRS.
- Weyerhaeuser and DNR studies of regrowth in Wildlife Area. Initial contact: Dick Ford.
- Erosion and sediment; delineation by reaches throughout watershed. Example reach: SRS is a sediment accumulation zone. Corps currently working on. In addition, USGS conducts periodic surveys of channel cross sections along North Fork Toutle above SRS to document long-term changes. USGS also periodically flies along the valley and takes pictures to document on-going erosion and sources of sediment. The quantity of sediment generated on a reach-by-reach basis has not been done due to funding limitations.
- Other available water quality data. Potentially Craig Graber Department of Ecology, Cowlitz County.
- Natural Resources Conservation Service (NRCS)—Revegetation research data?

- Other Data: USGS measures water and suspended sediment discharges along the lower Toutle and on South Fork Toutle. Also, using past relationships of sediment discharges among various basins along with annual estimates of sediment accumulation behind the SRS, the USGS keeps an updated estimate of suspended sediment flux along NF Toutle above SRS.

<u>Issues (technical, organizational/logistical)</u>

- Review status of MSH monument: scientific studies and management policies. Monument rules were legislated by Congress, and unless Congress indicates it may be willing to enact new law, this planning level analysis should assume no physical changes within the monument are likely.
- Need to verify the SIAM sediment model Corps is using will provide necessary information to evaluate alternatives.
- Effects of N1 structure on channel and processes above SRS.
- Potential loss of fish habitat in lower reaches of tributaries to North Fork of Toutle River due to avulsions. Avulsions attributable to changes in river. Loss of habitat also tied to quantity and caliber of sediment moved by the river.
- The WDFW Fish Collection Facility (FCF) functions poorly as trap because it fills up w/sediment. Results in "closure" of facility regularly and likely reduces number of fish returned to upstream tributaries. Limited funding contributes to deteriorating condition. Operation relies on dedicated volunteers.
- Fish passage upstream at SRS. Generally, migration upstream is desirable. Potential issue is associated with hatchery vs. wild fish passage – if fish free to pass upstream of SRS spillway it will be more difficult to prevent hatchery fish from passing upstream.
- Uncertainty on how braided reach above SRS impacts fish. Degraded fish habitat immediately above SRS.
- Degraded fish habitat in Lower Cowlitz.
- Degraded fish habitat in Lower Toutle.
- Degraded smelt spawning habitat in Lower Cowlitz.
- Need to quantify erosion, sediment deposition by reach throughout basin. There is disagreement what are the primary sediment sources. Elk Rock and Loowit Canyon area were identified by Corps subcontractor, WEST consultants, in a paper presented at the 7th Federal Interagency Sediment Conference in 2001.
- Loss of Lower Cowlitz River off-channel habitat/complexity due to levees, loss of beavers.
- There are different points of view about the elk winter range – winter kill common due to lack of forage due to wash out in bottomlands; Elk spend 10 months of year in river bottom.
- There is a need for stream/sediment gages (functional) in upper North Fork Toutle – difficult and many attempts have been made.
- There were concerns about "other" impacts such as navigation, flooding, human health, dredging, water treatment.
- Potentially, there may be flood and water quality issues in Lower Cowlitz that the Department of Ecology and Cowlitz County could provide information about.
- Concerns were expressed over potential levee failure (risk analysis), especially in conjunction with earthquakes, and that proposed levee raises could worsen problems.
- Review and summarize historical agreements, ownerships, etc (ownership and responsibility; lands vs. facilities)--should be included in reconnaissance study.
- Given tight Federal budget environment, non-Corps funding opportunities should be identified and if possible secured.

- Corps program will likely require non-Federal contribution (cash and in-kind supplies and services). Locals should determine if there is a willing umbrella non-federal sponsor.
- Locals should consider developing Joint Letter of Support (multi-agency, interest, etc).
- Fully engage with potential participants (e.g., DOT, County, LCFRB, general public, etc) to ensure coordination across jurisdictions, agencies, disciplines, interest groups.
- Role of NF Toutle Work Group. Prepare written statement to describe the roles of the Corps and Work Group throughout the planning and implementation process. For instance, the Advisory Group will serve in an advisory role rather than directing the Corps. Consider having a single point of contact representing Advisory Group who works with Corps point of contact.
- Verify ownership/management of "operational area" and material behind it.
- Focus of this meeting was on Corps General Reevaluation Report process and funding. Under Corps restoration planning process potential projects that benefit ESA species receive higher priority in demonstrating a federal interest.
- Individuals had different ideas on the extent of the project area to be considered.

<u>Potential Actions/Components of Ecosystem Restoration Plan</u>

- Modify SRS spillway for upstream fish passage (coho and/or steelhead). Specific modifications to consider include bottom waterfall, barrier at south side of spillway lip.
- Modify FCF to better function as trap. Currently, "closed" part of most weeks.
- Modify FCF to continue ability to trap but also allow "natural" upstream fish passage.
- Remove FCF.
- Above SRS, revegetate gravel bars by planting grasses, clover and use large woody debris to armor banks. However, the main sources of sediment along upper NF Toutle are from lateral erosion of, and small debris flows from, the valley walls carved on the debris avalanche deposit rather than remobilization of in channel bars. Therefore, plantings more suitable for preventing erosion due to runoff, not due to lateral channel migration.
- Use existing cobble above N1 to stabilize and create 2-year frequency flow channel.
- Upstream of N1, create overflow sloughs to absorb energy from high flow events and support development of broad floodplain.
- Install sediment trap(s) above SRS. Potentially would introduce another fish passage problem.
- Focus on stabilizing/protecting existing "good" habitat (grass, willows, alder).
- Import large woody debris for nutrients & pools/Bank erosion/sediment containment. State/privately owned timber could be used as potential source of timber.
- Revetments would be more effective bank stabilization tool than revegetation.
- Implement demonstration or trial habitat restoration downstream of Monument boundary to verify/improve effectiveness of potential measures.
- Design a mid-valley sediment trap above SRS, extending from mid section of spillway lip to mid-valley hill located 1-1/4 miles upstream from the SRS (purpose would be to establish stable fish passage on each side of valley from SRS area to tributaries with good habitat; also to reduce sediment flows through SRS).
- Stabilize SRS sediments.
- Create a low flow fish passage channel (1,000 cfs capacity) on northerly side of SRS spillway.
- Acknowledge and plan for ongoing non-Federal maintenance of revetment/vegetation actions.
- Monitor sources and amount of sediment entering NF Toutle.
- Improved access in NF Toutle is needed for monitoring/maintenance. Also, restore access roadway at SRS spillway abutment to concrete spillway slip.

- Stabilize North Fork Toutle upstream of SRS to reduce sediment downstream. Possibilities for engineered channel solutions such as log structures, overflow channels, use of existing cobble to reinforce banks, create berms to protect/enhance "good" habitat in tributaries to North Fork Toutle above SRS.
- Enable volitional passage through SRS spillway.
- Selective hunting of elk.
- Consider long-term dredge operation downstream of monument boundary to trap sediments. Use trapped sediments to restore habitat above N1.
- Local indicated an interest in developing their own team to explore and identify actions (such as demonstration trials) that they could implement quickly (before Corps planning process is complete).

Next Steps

1. Tim will synthesize and summarize notes from meeting.
2. Draft notes will be distributed to attendees.
3. The group agreed to review and comment to clarify and add additional details; to provide any other relevant existing data.
4. Revised notes/information will be sent out and serve to document the initial range of issues to be considered.
5. Corps team will flush out an outline for Reconnaissance Report based on feedback received.

List of Participants

Organization	Name/Title	Contact Information	
Steward and Associates Sustainable Fisheries Foundation	Cleve Steward	360-862-1255 csteward@stewardandassociates.com	120 Avenue A Snohomish, WA 98290
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AGENDA
Workshop Mount St. Helens General Reevaluation Report Study
Sponsored by the U.S. Army Corps of Engineers
and the Mount St. Helens Citizens Advisory Committee

February 13, 2006

I. Introductions and overview of meeting agenda

II. Review of the Corps of Engineers' historical and current activities related to sediment control, flood protection, navigation and ecosystem restoration in the Toutle and Cowlitz watersheds.
- Historical overview of authorities, emergency actions, temporary and permanent structures built
- Annual sediment report
- Sediment transport model
- Analysis of long-term sediment management alternatives

III. General Reevaluation Report Study (Phase I)
<u>Goal</u>: Drawing upon the best available information and professional expertise, study team members will prepare a Reconnaissance Report that analyzes existing conditions, determines whether the public would benefit by modifying those conditions, documents a Federal interest in doing so, and demonstrates that a viable plan of action can be implemented with a reasonable certainty of success.
- Congressional funding and direction
- Federal, tribal, state, local government, and stakeholder interests
- Study team composition and role
- Phase I Scope of Work (handout)
  - Range of issues to be considered
  - Types of actions to be considered
  - Sources of existing data
- Phase I schedule, budget and product
- Project Management Plan for feasibility study

IV. Feasibility Study (Phase II)
<u>Goal</u>: Depending on the recommendations of the GRR Report and funding availability, Phase II will comprise the preparation of a Feasibility Report, Implementation Plan, and associated environmental studies that evaluate alternative plans and recommend an action.
- Participants, Timeline and Funding Requirements
- Potential non-Federal sponsor (cost share partner) for Phase II and construction

V. Next steps and open discussion

VI. Adjourn

North Fork Toutle Workshop March 7, 2006
Mount St. Helens Silver Lake Visitor Center

Observations/Recommendations from the Audience

- Reforest upland areas
- Restore riparian vegetation
- Create single channels on either side of valley (may not work if system remains unstable)
- Protect tributaries
- Need to collate existing data, coordinate research across disciplines
- Release tagged adults above last falls on SRS spillway to see if they can ascend remaining portion of spillway
- Determine how much utilization of tributary habitat occurs
    - Juveniles (rearing)
    - Adults (spawning)

Phase I Recon Study

- Corps of Engineers leads study with input from the public – is there a federal interest?
- Identify issues, compile existing info, make recommendations regarding need for and scope of feasibility study (Phase II)
- Problems with fish passage are a legacy of project; fixes should be funded and addressed under existing authority
- Remove the SRS altogether? Would have to deal with problem downstream (e.g., dredge)
- Plug tunnel and breach Spirit Lake
- Intercept and stabilize sediments at their source
- It is realistic to think we can stabilize system? Is it too dynamic?
- How much habitat will we gain/lose under different alternatives?
- Reach by reach analysis – identify short- and long-term fixes
- Be sure to include lower reaches of tributaries
- Habitat below SRS is important too
- Enlarge breach in N1; divert flow toward center of channel
- N1 already forces channel toward breach, but some water runs toward sides.
- Fish Passage: SRS spillway and Fish Collection Facility (FCF)
- Restore volitional passage through SRS bypass channel (i.e., spillway)
- Consider creating a low flow channel in SRS spillway that fish can ascend at all flows
- Eliminate the 15’ waterfall at base of spillway
- Don’t recommend removing FCF; we need a way of separating hatchery and wild fish
- Recommend an incremental approach: modify spillway but keep FCF if it can be fixed (maintain our options, lower risk)
- Promote/maintain natural processes – let river take care of itself
- Don’t neglect other species – should address needs of entire aquatic community
- Preserve human uses and opportunities

Alder Creek and Hoffstadt Creek Site Visit
Memorandum for Record
October 6, 2006

Purpose:

Site visit to Alder/Deer Creek & Hoffstadt Creek Tributaries, Mount St. Helens in order to better understand the conditions at the confluences to the North Fork Toutle. In particular to assess existing fish passage issues, potential future fish passage issues and explore potential actions.

Participants:

Lou Reebs
Mark Smith (EcoPark Owner)
Cleve Steward
Shannon Wills
Al Donner
Patrick O'Brien
Jeremy Britton
Paul Cedfeldt
Tim Kuhn

Observations:

AM: Went to south side of North Fork Toutle River sediment deposition area at Alder Creek (old fish release site) and viewed area near the confluence with the North Fork Toutle River. Cleve Steward pointed out areas where the habitat was not optimal at lower flow conditions due to sediment buildup at the confluence. The channel seems shallower and subject to higher temperatures at low flow due to the lack of water depth. The confluence of Alder Creek with the North Fork Toutle is not well defined at low flows due to periodic migration of the NF Toutle channel and high sediment loads being carried by the North Fork Toutle. Potentially there is significant upstream fish habitat; uncertain passage concerns. Deer Creek could not be directly observed but appears good upstream habitat as well. Numerous photos were taken and are located on the project LAN site.

PM: Went to EcoPark along north side of sediment pool in the vicinity of Pullen Creek just upstream of the SRS. The property is owned by Mark Smith. Mark provided the team an extensive tour of various sites. First, team visited Pullen Creek and its confluence with sediment pool. In the last two years a small lake began forming where Pullen Creek just upstream of the confluence with the North Fork Toutle River. The historic confluence of Pullen Creek and the North Fork Toutle is upstream of the location of the SRS spillway and in the active sediment depositional area behind the SRS. The Pullen Creek watershed is small, and the creek may have been ephemeral or have very low base flow. It is likely that the sediments trapped by the SRS built up to the point where Pullen Creek did not have enough constant streamflow to maintain a connection with the North Fork Toutle and became blocked, forming a small lake. There no longer is a stream connection from this lake at edge of sediment pool and the North Fork Toutle River (likely subsurface flows still connect to North Fork Toutle). All indications are this newly formed lake will be "permanent." Next site visit was to look over sediment basin just above East Pullen Creek and observe on broader scale the impacts of sand build-up and resulting in the creation of a lake on East Pullen Creek as well. Next site visit was to go upstream in sediment pool to general vicinity of below Hoffstadt Bluff. The composition of the sediment pool is combination of sand with lots of gravels/cobbles. Mark Smith said that the boundary between all sand and sand mixed with coarser materials has moved downstream over the last two years (toward the SRS spillway. Numerous photos were taken and are located on the project LAN site.

Questions/Issues:

- What will likely happen to these new formed lakes a Pullen Creek? Continued buildup, stable now, permanent separation of Pullen Creek from North Fork Toutle, other?
- Distinct sediment types in sediment pool, as you move upstream from SRS. At Pullen Creek and below all sands; above Pullen Creek but below Hoffstadt Bluff visitor center mixed sand and gravels; at old N1 structure mostly cobbles (from previous site visit). The gradation and mixture of sediment types is a function of slope. As the overall slope of the sediment depositional area steepens, coarser sediments will be seen farther downstream. This was anticipated in the design, and is a result of the sediment pool filling and adjusting slope.
- In lower areas of sediment pool appeared there would be opportunity to seed grasses. It was suggested that trying different approaches would be useful; Mark was open to this on his property (extension service, university, other research?). Much of this land is owned by Washington Department of Transportation but they have not been active participants in future planning.
- It was suggested that log/rock grade stabilization measures in the reach above SRS to perhaps to N1 might be viable and provide stream stabilization and sediment control. Grade stabilization upstream may result in a more stable channel downstream.

North Fork Toutle River Fish Collection Facility Site Visit
Meeting Notes
October 27, 2006
10:00 am - noon

List of Participants: See attached list of participants.

Purpose: The site visit provided an opportunity for Corps of Engineers (Corps) staff, Washington Department of Fish and Wildlife (WDFW) staff, and other interested individuals to meet and discuss the current status of the North Fork Toutle Fish Collection Facility in order to develop an understanding of how it is currently operated and the issues associated with the facility.

The Corps is in the process of completing a Toutle river reconnaissance level evaluation in order to determine the potential for ecosystem restoration actions. A complete understanding of the FCF operation is a component of this effort. Prior to implementing any ecosystem restoration actions, it's imperative that there be resolution on how WDFW will operate and maintain their FCF. Otherwise, many potential actions related to fish passage would be ineffective. The WDFW has indicated ongoing operational issues with the FCF.

Summary of Meeting: For the initial half hour of the site visit individual participants described their backgrounds and perspectives on the fish collection facility. The group then proceeded to complete a quick tour of the facility in order to better understand how it currently is operated and what are the issues associated with the facility. WDFW provided the Corps a copy of their maintenance project list for their FCF (see attached list of items). For the balance of the site visit individuals and sub-groups explored in more detail the specific issues and documented their observations.

A summary of the issues and observations identified during the site visit follows. A diagram of the FCF is included.

Issues

Several issues were identified by the participants and they fall into four major categories: Operation and Maintenance, Mechanical, Electrical and Structural.

Operation and Maintenance

- The facility operators do not have the Operation & Maintenance manual or drawings at the site. Information that was sent to the State after completion of the project has been lost or was never forwarded to the facility operators. The present operators do not know how the facility was intended to be operated or maintained. The lack of an operating manual available to the current operators has made it difficult for them to know how the facility was intended to be operated or assess the functionality of specific components (Note that the Corps has located a copy of the manual and it will be provided to WDFW).
- Sediments, often several feet deep must be hand moved down the system out of the crowder section, a process taking many hours.
- The pump installed to supply a hose system to assist with suspending and moving sediments deposited in the trap is currently not functioning.
- The facility silt trap (Weir Box) near the river water supply is not used. This contributes to the mechanical difficulties with the crowders.

- It appears the FCF operators have removed/modified some of the ladder weirs from 'normal' position. Differences in standard weir drops (6"/weir at this facility) were estimated to be up to 2 feet. One of the modified positions is with the ladder weir sitting on wood cribbing making the orifice several inches above the floor.
- A large amount of vegetative debris tends to block flow through the gratings/louvers of the facility, and is causing a great deal of operation and maintenance challenges.
- The water supply pool had silty water with mats of vegetation in it when we first looked into the pool. The WDFW fishery crew had already made one fish processing run that day so it was a little surprising to see murky water with floating growths, mats, etc in the entry area for this supply pool (Weir Box). Normal operations by the crew is to operate the auxiliary water supply (diffuser channel) for about 1/2 hour then start the fish ladder supply channel and shut off the diffuser supply so that all water is going thru the water supply channel into holding pool and fish ladder.
- Once the crew determines that there are sufficient fish to process, the water supply is turned off and the holding (collection) pool is allowed to drain to about 8 to 12 inches deep and a person climbs down into the pool with a large net and collects the fish up against the walls. Fish are handed upward to another crew member who puts them into a small tank with CO_2 gas in the water. When fish are unconscious, they are then processed and put into the hauling truck.
- It appears that the 24" diameter sluiceway pipe (Weir Box Sluiceway pipe) located in the water supply pool (Weir Box) is never used. There is a steel bulkhead in a slot just downstream from the pipe entrance that is "dogged" off high in the air above the water. The bulkhead is supposed to be down resting on the sill and the water to the auxiliary water supply and the fish ladder water overflow and the sluiceway pipe is supposed to be used 24/7 to minimize sediment in the fishway, but neither event occurs. There is no bulkhead or slots available to shut off the water supply pool at its entrance. The steel barrier grating keeping debris from entering the water supply pool looks to be in good condition.
- Some of the fish ladder weirs have been moved out of sequence so that uniform vertical intervals are not present. Some of the weirs are simply removed and sitting/laying on the ground or leaning against the walls of the facility concrete structures.
- The lateral flows from the stilling basin area below the FCF results in the water elevation being low in the lower ladder and entrance during low flows. This along with an inoperable lower fish ladder gate, and perhaps some misplacement of the ladder weirs, contribute to lowering the water levels in the ladder such that the orifice(s) above the auxiliary water add-in area are not functioning properly, either blocking or creating difficult and potentially injurious passage upstream. To compensate for this problem during low river flow periods sheets of plywood and boards have been used to push down into a slot just above the add in water supply to create deep enough water above it to improve fish passage into the orifices. These practices likely reduce the attractiveness of the flows coming from ladder and trap section, and may be causing delays or rejection of fish passage. Improvements to the release sites and locations are needed as well.

<u>Mechanical</u>

- There are several non-functioning elements at the facility. From a fish handling perspective, the largest problems appear to be the holding pond crowder and the lock crowder. The lock crowder has been removed from its operational location. The holding pool crowder is in place, but not operational.
- The small crowder intended to "push" fish into the fish lifting structure has been dismantled and stored on the ground nearby. The big crowder for the holding pond is left up near the east

end of holding pool and not used because of the silt buildup on the floor. It appears that the lifting structure is not used to move fish into the hauling truck.

- Sand and silt is visible in the entry pool, in the holding pond, between the removable fish ladder weirs and in parts of the diffuser pool. It appears that the V-notch weir piece located in the downstream end of the holding pond is basically “stuck in position” as the sand and silt surrounds the bottom part. The large crowder is stored at the U/S end and is apparently not used. The silt and sand appears to be blocking the operation of the crowder as elevation of the sand/silt floor varies by several inches along the length and width of the holding pond.
- It was not determined if the lock filling system is functional. It is not being used at present, because the crowders do not function.

<u>Electrical</u>

- Apparently, there are some electrical issues, but lack of O&M manuals or drawings has precluded an electrician from making any changes.
- Two of the fish entrance bulkhead hoists are non-functional. The local controls are not capable of being energized (local disconnects are either broken or frozen in the ‘Off’ position). We were unable to tell if there was power available. Local operators were unsure if power was available either.

<u>Structural</u>

- A portion of the North Fork Toutle River stilling (retention) basin has washed away. The broken end sill structure at D/S end of stilling basin is fiber reinforced shotcrete about 8 inches thick laying on top of aggregate which appears to be naturally rounded gravels and small stones probably obtained from the river bottom at time of construction. This structure is being undermined by erosion process from the river and gradually breaks off in large chunks as load gets to be too much for the over hanging portion. The north and west ends of this shotcrete structure are broken off in large chunks up to 10 feet long. The absence of the structure on the north end allows the river (and fish) to go around the north end into the tailwater of the stilling basin and thence to the fish facility entrances. The entire downstream edge of the shotcrete mass is undercut by 5 to 6 feet and is about 6 to 7 feet above the water surface in the stagnant pool just to the end of this shotcrete structure. There is visible brown staining on the rock revetment and on the surface of shotcrete along the left side of the stilling basin at the downstream end.
- It appears that the reinforced concrete downstream end sill as shown on the contract and on As Built drawings may not exist. Looking at the area where this end sill is supposed to be located, there are no apparent signs of the end sill, just an expanse of shotcrete. It may be that a contract modification did occur but was not noted on As Built drawings that were found prior to this site visit.
- The water surface of the river on the downstream side of the broken shotcrete chunks is steep but fish seem to be passing satisfactorily thru this area to get into the trap entry pool. It appears that the water surface in the stilling basin adjacent to the entry pool is lower than original design but fish are still entering the facility. According to the 1990 O&M manual (page 1-4), degradation downstream of the fish barrier was anticipated and the FCF was designed to operate with a degradation of up to 6 feet.
- The portion of the fish barrier structure that is visible appears to be in good condition and is functioning as intended. The overflow notch on the left bank of the fish barrier structure has debris stuck in it. Only one of the two stoplogs is in place. The other concrete stoplog is laying on the ground adjacent to this part of the facility.
- The upstream embankment dam on south side (left side looking downstream) of river looks good. The gravel part at the top of the embankment is in good drivable shape and the

upstream concrete slab protecting the embankment looks good. No visible cracks or any undermining of the concrete slope identified.

- The on-site resident operator, who primarily operates the Green River facility, was asked about the septic system and he said that it appears to be working fine.
- The two concrete bridges were only given a cursory inspection. No visible cracks were seen on the roadway surface or the sides. Did not look under them as not possible to do so due to lack of access.
- Most of the steel hoist frames look to be in good condition except for a few small spots of rust in various places on these frames. The hoists have some rust showing for the chain cans.
- The access ladder for getting into the diffuser pool is showing considerable rust at or below the water surface. There are number of steel items that are not in use and lay on the ground in the grass or are leaning against the concrete walls. Some items have rust spots
- There are a number of small steel items stored in the grassy area within the facility which have rust spots on them. These items appear to be lifting beams and stoplogs and other miscellaneous equipment that don't appear to be used.
- The entry pool has a length of 2 inch steel pipe located near the downstream entrance slot. The bulkhead and fish barrier rack for the entry pool slot are now connected together and hang above this slot. The chain container can is rusted out in the middle area with visible holes about an inch or so wide. Some signs of rust are showing on some of the fasteners attaching the lifting frame to the concrete. The middle fish slot to the entry pool is jammed shut with the bulkhead and is apparently never used.
- The handrails and stairways in the facility all appear to be in good condition as no signs of rust or distress. The grating that covers the water supply channel and the diffuser access area looks to be in good condition. The fiberglass grating panels over the diffuser access area have moss growth along the overall length of these panels while all of the steel grating is clean along their entire lengths.

Conclusions/Observations

1. The Corps has located a copy of the operation manual (November 1990) and will provide to WDFW.
2. It appears substantial maintenance work is needed on components of the facility.
3. After WDFW personnel have had an opportunity to review the O&M manual they will need to investigate whether or not unused components of the facility could be brought back into operation and improve the overall effectiveness of the FCF.
4. The present dysfunctional nature of the FCF, many of which are noted in this trip report, has led to the use of some less than optimal "trap and haul" practices being needed to accomplish the capture and release of coho and steelhead above the SRS. Because the crowder system is not functional, fish that enter the trap are hand netted by personnel climbing down into the crowder section of the trap, lifted over the railing, carried to an evaluation table, examined and sampled, and then hand carried to a tank truck. These activities greatly increase the level of stress on trapped fish, and the possibility of injury. Fish being used in the ongoing studies of fish passage at and above the SRS are subject to these stressors as well as those involved with tagging, possibly affecting their passage and migratory behaviors.
5. A strategy to address the deficiencies is needed to limit negative effects on migrating salmonids. The deficiencies at the FCF have resulted in poor trap and haul techniques being unavoidable. Resolution of these deficiencies will be an important component of any plan to allow volitional upstream fish passage past the SRS. From the Corps perspective, the FCF is needed in the near term until adequate volitional passage past the

SRS can be accomplished. WDFW has not yet determined whether they want the trap and haul facility only in the absence of volitional passage or if they expect to operate it in the long-term, even if volitional passage improvements were implemented.

6. Any further investigation of the FCF will require discussions among the interested agencies. Funding is an issue with the Corps. One potential approach to consider is to use the Corps of Engineer's Planning Assistance to States program cost share program. Other options as identified should be explored.
7. A number of photos were taken. Corps Portland District will maintain copies on the project directory located: \\Nwd\nwp\ETDS\Mount_St_Helens\Photos\FCF 27Oct2006\\EC_DSPhotosOfT&H. Non-Corps individuals interested in copies should contact Tim Kuhn 503-808-4752.

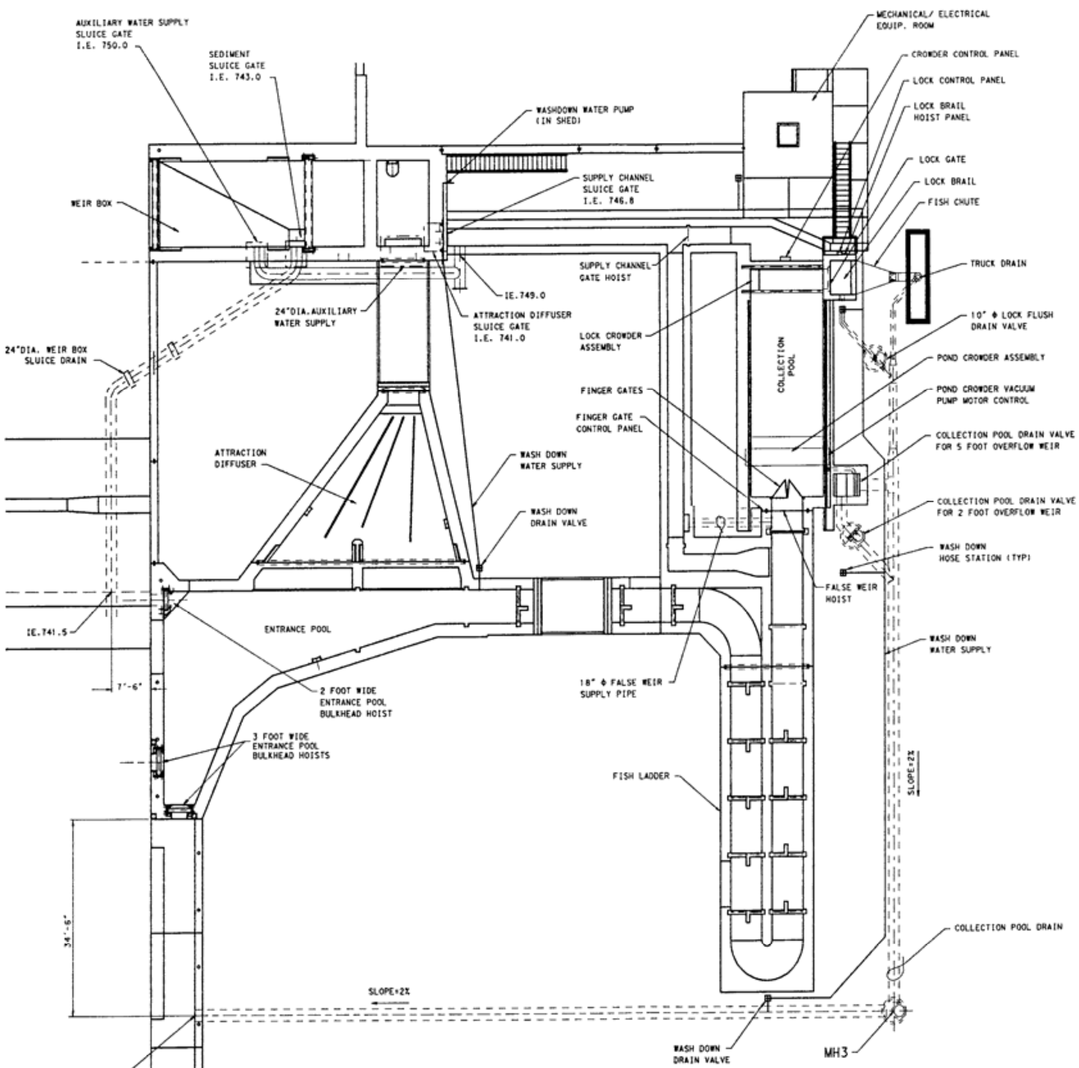

FIGURE 1-1 PARTIAL AREA PLAN

N.T.S.

List of Participants

Name	Organization	Contact Information
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WDFW Summary of Maintenance Project List for FCF

- Repair crowder and associated pump for moving silt.
- Install telephone or VHF (Work completed).
- Repair 2” (?) electric pump under stairs by diffuser, or find other source for 1-1/2” firehose.
- Make gate at lower fish ladder operational.
- Inspect and make recommendations regarding river gate beside the ladder gate.
- Replace Truck (Done).
- Replace fish hauling tank with larger, 650 gallon tank.
- Complete assembly and installation of fish tank fill chute (Done).
- Repair flumes at haul sites (Work in progress).
- R/R screen structure at head end of trap.

Trip Report – North Fork Toutle River Trap & Haul Facility

Date of Trip: 29 Nov 06
Date Prepared: 30 Nov 06

Participants: Michael Crump and Rick Mettler from the Corps of Engineers. There were four WDFW employees that included Julie Henning, Paul Peterson plus two other people that were there to operate the facility.

Purpose: The purpose of this visit was to make an assessment of the general condition of the facility after the flood event that happened around the 7 November, to discuss WDFW proposed maintenance and repair options and observe removal of the stoplog currently in place on the crest of the barrier structure. A crane crew was expected to be at the site to do this removal work.

General Comments regarding condition of the facility:

1. The facility site was covered with 3 to 4 inches of snow. Areas immediately adjacent to the river were coated with ice in 1/2 to 3/4 inch thickness. Near the downstream fish entrance damaged handrail and missing grating walkway were observed. A log that came down the river during the flood event caused this damage before it resumed moving downstream in the river.

2. It appears that the recent flood event in early November has deposited a considerable amount of silt and sand in front of the water intake structure. The exposed silt/sand bar extends 10 to 20 into the river and is several hundred feet long. Depth of water along most of the intake appears to be around 4 to 6 inches except in the vicinity just at the downstream part of the intake screen where it appears to be about a foot or so deep over a length of a several feet. The operators stated that the silt had been even higher but it has been gradually eroding during the last couple of weeks.

Note that a review of photos back around 1991 shows the river was located further south in the channel and that the channel points right at the entrance of the water intake structure. The river channel is now about 100 to 150 feet further northward of old channel location and, based on seeing willows growing on the upstream end of the sand bar, it has apparently been shifted for some time. I could speculate that this shift probably occurred in the widespread spring flood event of 1996 but don't know that as a fact.

3. Visibility into the river is no more than a foot due to the amount of silt and sand being carried in the water. It appears that the fore bay area of the fish barrier structure is almost completely full of sand and silt up to the height of the crest. The far side appears to be deeper than a foot or since no material was visible and currents could clearly be seen.

4. A deposit of sand and silt approximately 5 to 6 feet high was seen on the north side of the diffuser pool. The angle of repose was near 90 degrees as slope is basically vertical. Looking at the screens on D/S side of this diffuser shows sediment and small pumice stones are partially blocking the screens.

5. At the water supply diffuser that supplies the head of the fish ladder, the screen was plugged with sediment and small stones also. The two operators were using a rake to disturb the material in effort to get the materials to go thru the screen. Height of material U/S of the screen appeared to be about 12 to 15 inches higher than downstream side.

6. The fish holding pool had similar amounts of silt laying on the bottom as seen in the 27 Oct 06 site visit.

7. At the fish entrance pool it was observed that water was exiting at the entrance closest to the barrier structure and that water was coming into the entrance pool thru the entrance slot furthest downstream. Note that the middle gate is “froze” in the closed position and the downstream gate was open at all times because it couldn’t be operated. The control switches are inoperable as noted in the 27 Oct 2006 trip report for the facility. Don’t now if the U/S gate was ever closed but gate was apparently not operable either. All of water flow from the diffuser area and the D/S entrance was passing thru this U/S gate.

8. The operators attempted to water up the facility while we were there. The maximum amount of water passing thru the fish ladder didn’t even come to the top of the orifice opening in the weirs due to the plugging up at the water intake structure. This means the facility can’t operate as designed.

Specific Comments Regarding Proposed Operations of the Facility

9. We discussed the stoplog removal and all agreed that it should be the first thing done so that the river flow would increase next to the facility thus eroding the sediments now in front of the water intake at an increased rate. It may be enough to help with getting adequate water into the facility but consensus was that this may not be enough to erode the material sufficiently and that it might take a couple weeks to see any improvement in the situation.

10. We discussed the weight of the concrete stoplog pieces and determined that the larger stoplog currently laying on the ground was probably around 7800 lbs which made the smaller one out in the river to be lighter. We estimated that the smaller stoplog piece would weigh around 3000 lbs at most. The WDFW crane was said to be able to lift 8000 lbs maximum. I briefly looked at the snow covered lifting beam and told them it looked to be ok to use. During this discussion about the stoplog work we found out that the crane and the maintenance crew had been diverted to fix a water intake problem at one of their hatcheries and thus would NOT be coming today to this facility.

11. We discussed the chance of getting a backhoe or crane with a clamshell to remove the sediment in front of the water intake. It’s not real feasible as this would involve getting permits from the state of Washington and the Corps to dredge the sediment out of the river. It seemed likely that this process would take a lot of time just to obtain these permits. Julie said that winter steelhead are expected to start showing up in this facility by January so there is not much time to get things improved.

12. The second thing for the state people to do in regards to improving their operation of this facility was to try getting the 24 inch diameter silt/sand transport pipe within the intake structure cleaned out so that it could be operated 24/7 as originally designed back in the 1990’s time period.

13. It appears that repair work needs to be done on several of the hoists and/or controls within the facility as they don’t work. This includes the hoists for three gates in the fish entrance pool. All three of these gates need to be made operable. As a minimum, the electrical switches mounted on the fish entrance pool hoist frames need to be replaced. After that further repair can be determined.

14. We discussed the placement of the fish ladder weirs within the ladder system. It appears that they are not currently installed as intended according to the original design. The reason for being in this condition is unknown. We decided that it may be good idea to place these weirs back into the configuration originally intended. I counted weirs and it appears that there may be one or two missing as four or five empty slots were seen. The contract drawings showed only one empty slot. Two weirs were laying against the concrete walls.

15. Most of the diffuser screens in the main diffuser pool appear to be just slightly bent towards the downstream side. They apparently can be easily moved however. Julie asked if these screens could be temporarily suspended while they flushed sediment out of the diffuser each time they operated the facility. I told her that they probably could be suspended on the existing vertical plates using cables or pins and told her on of the WDFW engineers should be able to check plate capacity fro this kind of loading situation. I reminded her that fish would move into the diffuser and that they would have to be removed each time the facility was operated if the operators did suspend the screens.

16. In regards to the diffuser screen at head of the fish ladder I said that the top of the screen could be reattached to a pin(s) of some kind and thus allow the screen to rotated so that the bottom of screen would move enough so that flushing of sediment could be done easier. Told them that their engineers should be able to easily determine a method to do this.

17. A short discussion occurred about WDFW adding a small movable screen into the water supply channel leading to the holding pool to pick up leafs and twigs that fall into this channel. We agreed that it would be good idea.

18. A set of all As Built drawings (11” by 17” sized paper copies) of was given to the WDFW people and a copy of the Operational Manual prepared by the Corps back in the early 1990’s was also given to them. A CD with these items on it was also provided.

19. A copy of the WDFW Summary of Maintenance was given to us as FYI data. We were verbally told that the stoplog removal was supposed to be on the list but it was forgotten when the list was made.

20. Photos of this site visit are in the project folder located in \\Nwd\nwp\ETDS\Mount_St_Helens\Photos\FCF29NOV2006.

Michael Crump
NWP-EC-DS

US Army Corps
of Engineers ®
Portland District

Mount St. Helens Ecosystem Restoration
General Reevaluation Study
Reconnaissance Report

Appendix B

Mount St. Helens
Information Database

July 2007

Mount St. Helens Information Database

The database shown below is a more comprehensive accounting of data and information sources related to sediment, fish, and habitat restoration. The database was developed by Steward and Associates for the Corps' Portland District.

Author	Year / Page	Title / Comment	Spatial
Bechly	**1980**	**Mt. Saint Helens eruption, restoration of Columbia and Cowlitz River channels : technical paper. USACE Call # - QE 523 .S23 B4**	
	abstract	At an estimated cost of $221 million, a massive water and land fleet of dredging equipment was mobilized by the Portland District, U.S. Army Corps of Engineers, to begin the restoration. Flood control work requires significant completion by late October 1980, and navigation depths are being restored in increments to alleviate delays to vessel traffic.	Toutle, Cowlitz,
Bisson	**2005**	**Response of Fish to the 1980 Eruption of Mount St. Helens. 2005. In, Ecological Responses to the 1980 Eruption of Mount St. Helens. Dale, V.H., F.J. Swanson, C.M. Crisafulli, ed.**	
	167	The temporary NF Toutle River sediment structure blocked upstream salmon and steelhead migrations, but the South Fork Toutle River structure was equipped with a fish ladder that passed adult salmon and proved a means to assess numbers of returning fish. USACE, at the request of WDFW and numerous sports groups, removed the SF Toutle R. structure after 2 years.	Toutle
	167	Returning adults were scarce in the first 3 years after the eruption (Lieder 1989). The recreational fisheries for salmon and wild steelhead returning to the Toutle River were closed immediately after the eruption and remained so until 1987.	Toutle, Cowlitz
	170	In Hoffstadt Creek, which was scoured nearly to bedrock by posteruption debris flows, pool area has remained an almost constant 35% through 2002... In spite of the lack of pool habitat in Hoffstadt Creek, juvenile steelhead and coho stocked in the 1980s survived and grew at rates equal to or greater than those in relatively undisturbed streams in the region.	Hoffstadt, NF Toutle
	170	Bisson et al. (1988) studied coho salmon recovery in three Toutle River streams from 1983 to 1986... Coho salmon stocked in the study sites exhibited increasing summer production during this period despite poor physical habitat (less than 30% of the stream area in pools) and high temperatures. Juvenile coho salmon production was found to be twice as great as production rates of juvenile coho salmon stocked in nearby old-growth forested streams. The remarkable high productivity occurred during a period when summer temperatures in one of the streams reached 29.5 C, several degrees above the assumed lethal threshold for salmonid.	Toutle

Author Year Title Page	Comment	Spatial
	Bisson et al (1998) attributed this extraordinary productivity to an abundance of both aquatic and terrestrial food resources, caused in part by increased light levels and associated increases in net primary productivity and by a relative absence of predators and competitors. Peak temperatures in Herrington and Hoffstadt creeks frequently exceeded the 24 C assumed lethal threshold for salmonids during the 1980s, but episodes of these lethally high temperatures declined during the 1990s. In spite of potentially hazardous thermal conditions during the first 22 years after the eruption, all three streams continued to support salmon. Fish may have survived high temperatures by making temporary use of cool groundwater seeps and other thermal refugia, where these features were available.	
169	Winter survival of juvenile coho salmon was low in volcanically distributed streams, which they attributed to lack of in-channel habitat complexity and hiding cover.	Toutle
168	Emphasis on supplementing Toutle River populations with juvenile hatchery salmon ended about a decade after the 1980 eruption; however, transport of adult salmon and steelhead from the NF Toutle R. fish trap to Hoffstadt Ck. and the Green R. in continuing.	Toutle
167	Most salmon and steelhead returning to the Toutle River during the late 1970s and in 1980 before the eruption were hatchery-produced fish.	Toutle
167	Downstream-migrating smolts pass over the dam's spillway, a concrete channel 670 m long with an average slope of 7%. On average, 22% of the coho salmon smolts passing over the spillway received external injury from the spillway in 2001 and 2002 (Olds 2002). Impacts were found to be greater when velocities over the spillway were elevated from heavy rains and melting snow, which resulted in higher suspended-sediment levels and greater risk of external injury to the fish from striking the spillway surface or trapped wood debris.	SRS
167	Upon completion of the SRS it extended approx. 50 m above the streambed and 600 m across the NF Toutle R. valley... thus it is a barrier to salmon and steelhead using the upper North Fork Toutle R. watershed	NF Toutle
167	Olds (2002) reported suspended-sediment levels of 252 to 1970 mg/l during the salmon smolt emigration period of March through May from 2001 to 2003. These concentrations, combined with high water velocity, were linked to reduced smolt survival in the Toutle River on the basis of sediment tolerances of salmonids in laboratory studies.	NF Toutle

Author Year Title Page	Comment	Spatial
168	Numbers of steelhead redds observed in the mainstem of the SF Toutle R. rose from 0 in 1980 to an average of 5.7 redds/km in 1984 and further to 21.5 redds/km in 1987 (Lucas and Pointer 1987).	SF Toutle
167	Initially, sand accumulated at the FCF trap's intake, preventing fish from entering it. The problem became acute during the mid-1990s as the pool behind the [SRS] dam filled with sediment and large quantities of sand began passing over the spillway, aggrading the river near the fish-trap intake. The Corps has repeatedly improved access to the fish trap by removing sediment. The dam also caused sedimentation in the lower reaches of Alder Ck. And Hoffstadt Ck. when sediment-laden water pooled behind the dam deposited sand near the mouths of the two streams. This sedimentation caused severe degradation to some of the highest quality coho salmon and steelhead spawning areas that existed before the eruption.	NF Toutle
166	Before the 1980 eruption, the Toutle River system contained approx. 280 km of streams used by salmon, steelhead, and sea-run coastal cutthroat trout. Volcanic mudflows and the main debris avalanche in total inundated 169 km (58% of the length of streams available to anadromous salmonids), including the entire main stem of the Toutle River. Nonetheless, many fish survived and persisted during the early 1980s in tributaries of severely impacted mainstem rivers. For example, in 1981, juvenile coho salmon were present in tribs. Of the Green R., and steelhead and cutthroat trout were observed at high densities in several tribs. Of the south and north forks of the Toutle River.	Toutle
166	The [post eruption] mudflows contained exceptionally high suspended-sediment levels (> 10,000 mg/l), with a peak suspended-sediment concentration of 1,770,000 mg/l being recorded in the Toutle River.	Toutle
170	Two factors would improve the recovery of fish habitat in Mount St. Helens streams: (1) reestablishment of riparian vegetation, which would moderate stream temperatures, and (2) recruitment of large woody debris, which would provide physical cover in winter. It's estimated the 5 to 20 years would be needed for riparian vegetation to provide effective shading for productive fish habitat and that 50 to 75 years would be required for new wood to be recruited from riparian forests.	Toutle
166	Physical changes to the rivers and to the chemical properties of the water were so great that ... many fish strayed from their river of origin... Estimates of adult steelhead straying from volcanically impacted river increased from 16% preeruption to 45% posteruption... Small numbers of adult salmon and steelhead, however, did navigate sediment-laden waters of main-stem rivers to return to small tribs. Of the Cowlitz and Toutle rivers in 1980, where they presumably spawned.	Toutle, Cowlitz
166	During the summer and early fall of 1980 suspended sediment levels in the Toutle River remained at 300 to 100 mg/l, a range that was found to be lethal for fish exposed to Mount St. Helens mudflow and tephra particles.	Toutle

Author	Year	Title	
	Page	Comment	Spatial
	175	Most experts held a pessimistic view of the prognosis for long-term recovery immediately after the eruption because changes in streams were so extreme. Twenty-two years after the eruption, many stream habitats and fish communities had returned to levels commensurate with the range of conditions found in Southwest Washington streams not affected by the volcano. Recovery has occurred more quickly than originally thought	Toutle, Cowlitz
	167	Exposure of juvenile steelhead to relatively low (500 mg/l) and high (2000 to 3000 mg/l) levels of Mt. St. Helens ash for 48 hours found fish were able to tolerate this relatively short exposure to volcanic sediment without exhibiting prolonged physiological stress responses.	Toutle, Cowlitz
	167	The two major Toutle River tribs. (SF Toutle R. and Green R.) eroded through mudflow or tephra-fall deposits and returned to preeruption streambeds within a few years.	SF Toutle, Green
Bisson	**1988**	**Summer Production of Coho Salmon Stocked in Mount St. Helens Streams 3-6 Years after the 1980 Eruption. Transactions of the American Fisheries Society. 117:322-335.**	
		Bisson et al. (1988) studied coho salmon recovery in three Toutle River streams from 1983 to 1986. Coho salmon stocked in the study sites exhibited increasing summer production during this period despite poor physical habitat (less than 30% of the stream area in pools) and high temperatures. Juvenile coho salmon production was found to be twice as great as production rates of juvenile coho salmon stocked in nearby old-growth forested streams. The remarkable high productivity occurred during a period when summer temperatures in one of the streams reached 29.5 C, several degrees above the assumed lethal threshold for salmonid. Bisson et al (1998) attributed this extraordinary productivity to an abundance of both aquatic and terrestrial food resources, caused in part by increased light levels and associated increases in net primary productivity and by a relative absence of predators and competitors. Peak temperatures in Herrington and Hoffstadt creeks frequently exceeded the 24 C assumed lethal threshold for salmonids during the 1980s, but episodes of these lethally high temperatures declined during the 1990s. In spite of potentially hazardous thermal conditions during the first 22 years after the eruption, all three streams continued to support salmon. Fish may have survived high temperatures by making temporary use of cool groundwater seeps and other thermal refugia, where these features were available.	Toutle
Crawford	**1986**	**The Recovery of Surviving Fish Populations Within the Mount St. Helens National Volcanic Monument and Adjacent Area, in Mount St. Helens Five Years Later, ed. S.A.C. Keller.**	
	abstract	Report seems to be exclusively on lake dwelling fish and does talk specifically about cutthroat.	Toutle, Cowlitz, Lewis
Cummans	**1980**	**Mudflows resulting from the May 18, 1980, eruption of Mount St. Helens, Washington : hydrologic effects of the eruptions of Mount St. Helens, Washington. USACE Call # - QE 523 .S23 C8 1981**	

Author	Year	Title / Page	Comment	Spatial
		B1 (abstract)	Report describes the location and chronology of the mudflows which followed the May 18 eruption. Average velocities are presented for the mudflows in the South and North Fork Toutle Rivers, and photographs illustrate the character of the debris and mud deposits.	Toutle, Cowlitz
Curl	**1980**	**Downstreams Fisheries, from On the Effects of the Mount St. Helens Eruption on Water Resources. Vancouver, Washinton. June 12, 1980.**		
		53	We were on an oceanographic cruise just after the eruption... 18 days working off the mouth of the Columbia because of the volcanic material coming down the river. We made measurements of salinity and turbidity distributions, of chemical composition, and of the physical state of the material that was coming down the river.	Columbia
Dammers	**2002**	**Northwest Power Planning Council. Cowlitz River Subbasin Summary DRAFT.**		
		13	All Toutle coastal cutthroat are considered one stock (WDFW 2000). Entry into the North Fork Toutle peaks between September and November, with a smaller number of fish moving throughout the winter (WDFW 2000). Spawning time occurs from January to June, and genetic data is unavailable for this stock (WDFW 2000). The status of the Toutle coastal cutthroat is depressed, based on chronically-low escapement measured at the Toutle River Fish Collection Facility and the North Toutle Hatchery, a long-term negative trend in the Columbia River catch from RM 72 to RM 48, and the habitat destruction from the 1980 eruption of Mt. St. Helens (WDFW 2000).	Toutle
		20	Annual surveys show the greatest abundance of adult fall chinook on the North Fork Toutle River to be in a five-mile stretch from the Toutle River Hatchery (1/2 mile up the Green River) to Kid Valley Park on the North Fork Toutle.	North Fork Toutle
		6	TAG members with the WDFW state that the FCF is inoperable much of the time due to sediment that jams the doors. This has occurred at crucial times during adult fish migration, and they have been unable to allow any adult passage when heavy sediment loads are moving through the system.	FCF
		5	Floodplain and wetland habitat along portions of the lower Cowlitz and Toutle Rivers was filled with the dredge spoils. Stream systems are recovering slowly from the effects of the eruption; however, elevated sediment loads, channel widening, lack of large woody debris and riparian cover all remain problems today.	Lower Cowlitz, Toutle
		39	Downstream migrating smolts are able to pass the SRS volitionally. From 1995 through 2000, the fish facility passed upstream to spawn an average of 184 (range 123-238) wild winter steelhead, 67 (15-153) wild cutthroat and 243 (87-633) coho adults. Spawning surveys are also conducted to monitor the spawning activity in the Toutle basin.	FCF, SRS, NF Toutle

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20	An average spawning escapement of 2,700 fall chinook was observed from 1968 to 1972, with a sharp increase beginning in 1971. Fall chinook were observed as far upstream as Spirit Lake (WDF 1973).	Toutle
18	In the early 1950s, the estimated annual spawning escapement was 400 spring chinook in the upper Toutle River / The current estimated return is 164 fish (WDW 1990).	Upper Toutle
15	Naturally spawning Toutle coho currently spawn in all accessible tributaries, are considered depressed, and show signs of a long-term negative trend (WDF et. al. 1993) / The run-size of naturally spawning segment for 1972-1979 was estimated to be 1,662 fish, based on average rack returns of 14,406 fish (WDW 1990) / Hatchery fingerlings were seeded in the watershed beginning in 1983 and this continued at least until the writing of the SaSSI report in 1993 / A number of tributaries in the Toutle River have good production potential; among these are Stankey and Outlet creeks (WDF et. al. 1993).	Toutle
15	Toutle River coho were, generally, an early-returning stock (Type-S), with most fish returning from August through October. Late runs are also present. Early Toutle River coho are generally more southerly distributed in the ocean than the early component of the Cowlitz stock (WDW 1990).	Toutle
32	The 1980 eruption of Mount St. Helens severely impacted salmonid populations and their habitat. Yet, most stream systems are naturally recovering from the disturbance. The North Fork Toutle is one exception were recovery has lagged behind. The slow recovery is believed to be the result of the Sediment Retention Structure (SRS) that has altered natural recovery processes.	Toutle
20	An average of 10,756 adults returned each year to the Toutle River basin from 1964 through 1979 (pre-eruption). Of these, natural spawners of both hatchery and natural origin in the Toutle subbasin averaged 6,573 fish from 1964 through 1979 with the following distribution: 4.8 percent from the mainstem, 3.8 percent South Fork Toutle, 49.4 percent North Fork Toutle, and 42 percent Green River (Kreitman 1981 as cited in WDW	Toutle

Author	Year	Title		
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	11	Summer steelhead were introduced into the Toutle river in 1968 (WDW 1990). The WDFW management objective is to provide a sport harvest in the Toutle River of 3,000 fish.		Toutle
	10	The mainstem North Fork Toutle River has been planted with hatchery steelhead since 1953 (WDF et. al. 1993). No historical production estimates are given for this stock. Currently, winter steelhead spawning occurs in Hoffstadt, Outlet, Alder, and Deer creeks (WDF et. al. 1993). Current winter steelhead stocks are considered depressed based on chronically low returns. Spawning escapements were estimated from 1989 through 1992 with a low of 18 in 1989 and a high of 322 in 1992. The stock will likely remain depressed until spawning and rearing habitat in the mainstem improves from the 1980 eruption of Mt. St. Helens (WDF et. al. 1993). There has been no escapement goal set. The mean escapement from 1991 to 1996 for the mainstem North Fork winter steelhead was 185 fish. It is estimated that from 1991 to 1996, none of the run was from hatchery fish (LCSCI 1998).		North Fork Toutle
	32			Toutle
	20	The estimated annual escapement of fall chinook in the Toutle and its tributaries in the early 1950s was 6,500. An estimated 80 percent of the total Toutle fall chinook run spawned in the lower five miles of the mainstem Toutle (WDF 1951).		Toutle
Dinehart		**Sediment transport at gaging stations near Mount St. Helens, Washington, 1980-90: data collection and analysis. USACE Call # - QE 75 .G3 PP 1573**		
	1	Sediment discharge and changes in sediment transport are summarized from data collected at stream-gaging stations near Mount St. Helens during the years 1980-1990. The objectives of the monitoring program include collection of data for calculation of total sediment discharge, computation of daily suspended-sediment discharge, and detailed observations of unique sediment-laden flows. Most sediment data were collected at gaging stations on the Green R., N. Fk. Toutle, S. Fk. Toutle, Toutle R., Cowlitz R., Clearwater Ck., and Muddy R.		Toutle, Cowlitz
Dunne	**1981**	**Flood and sedimentation hazards in the Toutle and Cowlitz River System as a result of the Mt. St. Helens eruption, 1980 : review and assessment for the Federal Emergency Management Agency (FEMA). USACE Call # - TC 424 .W2 F56 1981**		
	i (summary	This study looks at four flooding and sedimentation hazards: (1) potential for catastrophic breaching of Coldwater and Castle Creek lakes; (2) potential for mudflows and floods generated by pyroclastic flows; (3) rain and snowmelt floods; (4) sediment transport, deposition, and channel changes.		Toutle, Cowlitz

Author	Year / Page	Title / Comment	Spatial
Durkin	**1980**	**Downstreams Fisheries, from On the Effects of the Mount St. Helens Eruption on Water Resources. Vancouver, Washinton. June 12, 1980.**	
	51	May purse seine catches of yearling salmonids (coho, sockeye, spring chinook, and steelhead) were comparatively low though over 800 subheading fall chinook were captured.	Columbia estuary
	49	On Monday May 19, various water-quality parameters were monitored in the: (1) Columbia R. upstream of the Cowlitz (2) Cowlitz R. and (3) Columbia at its confluence with the Cowlitz. Water temp., turbidity (JTU), dissolved oxygen (D.O. in mg/l), and pH were among the factors measured. Initially (May 19) turbidity in the Cowlitz River exceeded 5600 JTU; the Columbia at the confluence was 3500 JTU and the Toutle was reported to be half water half silt late on May 18.	Columbia, Cowlitz
Evans	**1980**	**Downstreams Fisheries, from On the Effects of the Mount St. Helens Eruption on Water Resources. Vancouver, Washinton. June 12, 1980.**	
	47	The depths of mud and water on the Toutle when it went by the mouth of the Green River was considerable. The Green River was diverted and flowed right through the [North Fork Toutle] hatchery complex... this could be as much as a $6 million annual loss to the fisheries.	Hatchery, Green
Harnly	**1984**	**Mount St. Helens : an annotated bibliography. USACE Call # - Z 6033 .E1 H36 1984**	
	ix-x	Caroline Harnly presents a lengthy and apparently very thorough annotated bibliography. The references have been divided into fourteen broad subjects: Mount St. Helens Before March 20,1980; General Mount St. Helens Information; Geologic Studies; Atmospheric and Climatic Studies; Chemical and Physical Studies; Effects on Agriculture; Biological and Environmental Effects; Medical and Health Effects; Business, Commercial, and Economic Implications; Industrial and Engineering Aspects; Social and Cultural Aspects; Special Maps; Dissertations; and Books.	Columbia, Cowlitz
	ix-x	Caroline Harnly presents a lengthy and apparently very thorough annotated bibliography. The references have been divided into fourteen broad subjects: Mount St. Helens Before March 20,1980; General Mount St. Helens Information; Geologic Studies; Atmospheric and Climatic Studies; Chemical and Physical Studies; Effects on Agriculture; Biological and Environmental Effects; Medical and Health Effects; Business, Commercial, and Economic Implications; Industrial and Engineering Aspects; Social and Cultural Aspects; Special Maps; Dissertations; and Books.	Columbia, Cowlitz
	ix-x	Caroline Harnly presents a lengthy and apparently very thorough annotated bibliography. The references have been divided into fourteen broad subjects: Mount St. Helens Before March 20,1980; General Mount St. Helens Information; Geologic Studies; Atmospheric and Climatic Studies; Chemical and Physical Studies; Effects on Agriculture; Biological and Environmental Effects; Medical and Health Effects; Business, Commercial, and Economic Implications; Industrial and Engineering Aspects; Social and Cultural Aspects; Special Maps; Dissertations; and Books.	Columbia, Cowlitz

Author	Year	Title	
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Hopman	**1982**	**An update on dredging activities in the Pacific Northwest, in Willey, R.G., ed., Seminar on attaining water-quality goals through water-management procedures, Dallas, Texas, 17-18 Feb. 1982. Proceedings: Washington D.C., U.S. Army Corps of Engineers Committee on Water Quality, p. 135-142.**	
	136	WDFW officials encountered significant numbers of steelhead that could only have originated from Columbia River waters, especially significant because turbidity levels were still in the neighborhood of many thousand JTUs and up until this time, those levels had been reported as fatal to anadromous fish species.	NF Toutle
Hubbell		**Characteristics of Columbia River sediment following the eruption of Mount St. Helens on May 18, 1980. USACE Call # - QE 75 .G3 C 850-J**	
	J1 (abstract)	Measured suspended-sediment discharges indicate that material is being scoured from the reach of the Columbia River directly seaward from the Cowlitz River mouth at Columbia River mile (CRM) 68.0, and that some of the scoured material is redeposited between CRM 63.8 and CRM 54.0. Most material in transport is of silt and clay size. Pumice particles larger than 2.0 mm in diameter are randomly distributed throughout the bed material (bottom sediment). Mean size of bed material finer than 2.0 mm in the reach directly seaward from the Cowlitz mouth is less than half the size of similar material directly upstream from the mouth and is somewhat finer than pre-eruption material. These values are similar to comparable values for bed materials at CRM 106.4. On the basis of this information, corrections for unusual sediment properties are not necessary in sediment-transport or dredging-earthwork computations for the Columbia River.	Cowlitz, Columbia
James	**2006**	**Oncorhynchus mykiss: Assessment of Washington State's Anadromous Populations and Programs. Washington Department of Fish and Wildlife, Olympia, WA.**	
	Chp. 7, 35	Through population viability analysis the NF/Mainstem Toutle Winter population has been identified as High risk for extinction based on an estimated extinction probability that exceeded20% in 20 years	Toutle
	Chp. 7, 30	Current and pre-settlement production potential (equilibrium adult abundance) for Toutle winter steelhead are 932 and 5,292, respectively. This equates to an 82% loss.	Toutle
		see included tables "Steelhead Historical Database"	Lower Columbia
	Chp. 7, 22	Presents average escapement in 1994 through 1998, 1999 through 2004, % change in escapement, and SaSI status for the Mainstem/NF Toutle Winter population.	Toutle

Author	Year	Title		
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	Chp. 7, 34	Reports number of observations and p-values for regression model and two predictor variables (spawners and SAR index) for recruits per spawner produced natural-origin Mainstem/NF Toutlewinter steelhead.		Toutle
Jones	**1986**	**The status of anadromous fish habitat in the North and South Fork Toutle River watersheds, Mount St. Helens, Washington, 1984. Fisheries Research Institute, University of Washington, Report 8601. Seattle.**		
	viii (from	Juvenile salmonids occur in tributaries in the North and South Fork Toutle River watershed, except those North Fork tributaries draining the landslide debris-flow areas.		North and South Fork
	viii (from	The eruption of Mount St. Helens destroyed 218 km of the 280 km (77%) of the anadromous salmonid habitat in the Toutle River drainage. In the summer of 1984, channel morphology, instream cover, riparian vegetation, and juvenile salmonid distribution were studied in impacted and unaffected tributaries of the North and South Forks of the Toutle River. The studies reported the status of stream channel recovery and riparian zone revegetation, the condition of existing salmonid habitat and instream cover, and the distribution of juvenile salmonids. Tributaries of the North Fork Toutle River and reaches of the South Fork have created new channel or re-developed old stream beds to near pre-eruption levels. Woody debris and riparian timber exposed during this process contributed to rapid channel development and formation of preferred fish habitat. Tributaries with the large woody debris removed developed slower as evidence by channel instability, the absence of well-defined pools, and a greater incidence of riffles. The regrowth of riparian trees which promotes channel stability, moderate water temperature, and provides large organic debris will determine the time frame of habitat recovery. The input of large organic debris resulting from riparian trees will occur in less than 50 years in tributaries throughout the lower and middle portions of the Toutle River watershed. The absence of riparian trees on the landslide debris flow and in the upper portions of the South Fork Toutle watershed will retard the recovery of salmonid habitat in these areas.		Toutle
Kock	**2006**	**Migration Behavior of Radio-Tagged Adult Coho Salmon in the Upper North Fork Toutle River, Washington. DRAFT REPORT OF RESEARCH.**		
		The first empirical data of movement patterns of individual adult coho within the study area (FCF, SRS, upper North Fork Toutle River and tribs).		FCF, SRS, upper NF
	viii	Did not observe upstream passage of radio-tagged adult coho salmon into or through the SRS spillway.		SRS
	12	Study represents movement patterns of just a few individuals that were present within the system for a few months in a single		FCF, SRS, upper NF
	11	Upstream passage through the sediment plain may be flow dependent.		SRS

Author	Year	Title	
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	11	Data suggest that the last downstream waterfall of the SRS spillway serves as an upstream barrier to passage of adult coho salmon.	SRS
LCFRB	**2004**	**Lower Columbia Salmon Recovery and Fish & Wildlife Subbasin Plan. Volume II – Subbasin Plan Chapter E – Cowlitz, Coweeman and Toutle.**	
	E-416	Riparian conditions in all important anadromous subwatersheds are uniformly rated by IWA as moderately impaired.	Toutle
	E-395	Reports Toutle River cutthroat sport harvest, 1972-1994; Toutle River fish collection count, 1991-1994; N. Toutle Hatchery trap count, 1989-1994	Toutle
	E-401	NF Toutle reach 10 has the highest EDT restorative potential of any spring chinook reach in the system.	NF Toutle
	E-395	Lamprey abundance is limited and does not exist for the Toutle Basin population. However, based on declining trends measured at Bonneville Dam and Willamette Falls it is assumed that Pacific lamprey have also declined in the Toutle.	Toutle
	K-407	Key EDT reaches for fall Chinook in the Toutle Basin area located primarily in the South Fork and North Fork Toutle with an emphasis on reaches lower in the system (Figure 10). Sediment has had the greatest impact, followed by channel stability, habitat diversity and temperature.	Toutle
	E-415	Reports the results of IWA analysis.	Toutle
	K-411	Subwatersheds in the NF drainage are susceptible to hydrologic impacts due to vegetation destruction caused by the 1980 eruption. This risk is mitigated by low road densities (0-2.7 mi/sq mi) and large amounts of wetland area (>10%). The exception is the South Coldwater Creek subwatershed (30103) and the NF Toutle below Maratta Creek (30306, 30302), which have high road and stream crossing densities.	NF Toutle
	K-412	The mainstem NF Toutle suffers from high road densities (6.6 mi/sq mi) and low mature forest vegetation coverage (33%).	NF Toutle
	E-480	Toutle River anadromous fish populations will also benefit from regional recovery strategies and measures identified to address habitat conditions and threats in the Columbia River mainstem and estuary. A series of specific measures are detailed in the regional plan.	Toutle
	E-451	Reports prioritized measures for the Toutle River Basin.	Toutle
	E-441	Lower Toutle mainstem reaches were heavily impacted by mud and debris flows during the 1980 Mount St. Helens eruption. Further degradation to channel, riparian, and floodplain conditions was caused by channel dredging and floodplain spoils placement in an effort to increase flow conveyance following the eruption. Effective recovery measures will entail reducing channel confinement and restoring riparian areas.	Toutle

Author Year Title Page	Comment	Spatial
E-447	Reports a summary table of reach- and subwatershed-scale limiting factors in priority areas.	Toutle
K-407	In the lower Toutle mainstem, where the majority of important reaches for chum are located, habitat has been negatively impacted by sediment, habitat diversity, and channel stability.	Toutle
E-442	North Fork Toutle recovery emphasis is for restoration of watershed processes throughout the NF basin including addressing the dense road network and heavy harvests. Emphasis should also be placed on addressing the continued supply of sediment from the SRS, which has become a persistent limiting factor for fish in downstream reaches.	NF Toutle
E-389	North Fork Toutle total escapement counts from 1989-2001 ranged from 18-322 (average 157)	NF Toutle
E-397	The SRS is considered a major source of sediment in the mainstem North Fork and its existence is believed to be preventing the recovery of the system (Wade 2000).	NF Toutle
E-417	The main threats from North Fork Toutle hatchery steelhead are potential domestication of the naturally-produced steelhead as a result of adult interactions or ecological interactions between natural juvenile salmon and hatchery released juvenile steelhead. Potential for interaction between wild and hatchery adults is expected to be low because of relative numbers of natural and hatchery fish and temporal and spatial segregation.	Toutle
E-441	The North Fork Toutle reaches with the most (restoration) potential are located just downstream of the Green River confluence and further upstream on the NF between Hoffstadt Creek and Castle Creek (reach NF Toutle 13).	NF Toutle
E-417	The main hatchery threats from the North Toutle Hatchery salmon programs are domestication of natural fall Chinook and coho and potential ecological interactions between hatchery and natural juvenile salmon.	Toutle
E-416	In the lower NF Toutle, the large percentage of industrial timber lands and high road densities suggests that trends are likely to remain stable.	NF Toutle
E-389	Reports Wild winter steelhead total spawning escapements for the North Fork Toutle and Green Rivers	Toutle

Author Year Title Page	Comment	Spatial
E-396	Water temperatures in the upper Toutle basin are thought to be high due to channel widening and loss of riparian cover associated with mud and debris flows. Temperatures near the mouth of the Green River at the Toutle River Hatchery often exceed state standards. The Green River and Harrington Creek (South Fork Toutle tributary) were listed on the State's 1998 303(d)list for elevated water temperatures (WDOE 1998). High suspended sediment and turbidity are considered major limiting factors in the North Fork and mainstem Toutle, restricting suitable fishhabitat to tributary streams. Nutrient problems may exist in the Toutle basin as a result of low steelhead, chinook, and coho escapement (Wade 2000).	Toutle
E-388	The historical NF Toutle winter steelhead adult population is estimated from 7,000-15,000 fish. Current natural spawning returns are 100-300.	NF Toutle
E-148	They report known, presumed, and potential fish use (GIS).	Toutle
E-388	In the NF Toutle River winter steelhead spawning occurs primarily in the mainstem, Alder, and Deer creeks. Spawning time is March to early June. Juvenile rearing occurs both downstream and upstream of the spawning areas. Juveniles rear for a full year or more before migrating from the Toutle basin.	NF Toutle
E-396	The Upper Toutle Watershed Analysis found that 55% of the upper basins have the potential for an increase in peak flow volumes of over 10% due to a lack of mature coniferous stand structures.	NF Toutle
E-388	Limited age composition data for Toutle River winter steelhead indicate that the dominant age class is 2.2 (58.6%)	Toutle
E-396	Low summer flows in Outlet Creek were identified in the Silver Creek Watershed Analysis as a problem for juvenile rearing (Weyerhaeuser 1994).	Toutle
E-384	In 1951, WDF estimated fall chinook escapement to the Toutle River was 6,500 fish	Toutle
E-443	North fork Toutle River limiting factors are reported to be: habitat connectivity, stream flow, water quality, substrate / sediment, habitat diversity, channel stability, and riparian function	NF Toutle
E-394	Coastal cutthroat abundance in the NF Toutle and Green rivers has not been quantified but the population is considered depressed.	Toutle
E-398	Following the eruption of Mount St. Helens, significant floodplain loss occurred due to the dredging and placement of sediment in the floodplain and near-stream wetlands, essentially creating levees along the channel. Floodplain disconnection has occurred on several Toutle River tributaries as well, also as a result of diking, channel incision, and dredging (Wade 2000).	Toutle
E-53	Reports Recent average hatchery returns and estimates of natural spawning escapement in the Toutle River basin by species.	Toutle

Author Year Title Page	Comment	Spatial
E-380	They report land ownership data (GIS).	Toutle
E-394	Anadromous cutthroat enter the Toutle from September-December and spawn from January through June. Most juveniles rear 2-4 years before migrating from their natal stream.	Toutle
K-403,	Reports the results of EDT analysis	Toutle
E-19	Smolt density model natural production potential estimates were made on various sections of the Cowlitz River basin: 123,123 smolts for the lower Cowlitz River, 131,318 smolts for the Tilton River and Winston Creek, 155,018 smolts above Cowlitz Falls, 142,234 smolts for the Toutle River, and 37,797 smolts for the Coweeman River	Cowlitz, Toutle
E-376	Align Hatchery Priorities Consistent with Conservation Objectives	Toutle
E-389	Between 1985-1989, an average of 2,743 winter steelhead escaped to the Toutle River annually to spawn	Toutle
E-397	Following the eruption of Mount St. Helens, some channels in the NF and SF Toutle basins re-developed pool habitats to near pre-eruption levels, however, pool quality was generally low (Jones and Salo 1986). Large sediment loads will likely continue to reduce the quality of pools throughout the Toutle system. Side channel habitat may be created in the upper Toutle channels that experienced debris flows, though adequate LWD and riparian cover necessary for good side channel habitat will take a long time to develop (Wade 2000). Side channel habitat in the Silver Lake basin is lacking (Weyerhaeuser 1994).	Toutle
E-19	The Toutle River system likely provided the most productive habitat in the Cowlitz basin in the 1960s and 1970s, but was greatly reduced after the 1980 Mt. St. Helens eruption	Toutle
E-375	Manage Growth and Development to Protect Watershed Processes and Habitat Conditions	Toutle
K-412	The lower NF Toutle (70301) has poor IWA values for road density (7.1 mi/sq mi) and mature forest cover (23%).	NF Toutle
E-418	Reports recent average hatchery returns and estimates of natural spawning escapement in the Toutle River basins by species, 1992 - present.	Toutle
K-407	For winter steelhead in the Toutle basin many of the important reaches and the habitat factors affecting them are similar to those for fall Chinook but with less emphasis on reaches lower in the system.	Toutle
E-51	Current North Fork Toutle River hatchery release goals are 2.5 million sub-yearling fall Chinook, 800,000 early-stock coho smolts, and 50,000 summer steelhead (from Skamania Hatchery) smolts	Toutle

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E-377	Manage Fishery Impacts so they do not Impede Progress Toward Recovery	Toutle
E-45	Reports IWA results for the Lower Cowlitz Watershed	Lower Cowlitz
E-376	Reduce Out-of-Subbasin Impacts so that the Benefits of In-Basin Actions can be realized	Toutle
E-18	Average total escapement of natural coho to the Toutle River was estimated as 1,743 for the years 1972-1979, prior to the 1980 eruption of Mt. St. Helens	Toutle
E-384	Building of chum salmon spawning channel and construction of coho overwinter habitat with alcoves, side channels, or engineered log jams. Benefits will be temporary but will help bridge the period until normal habitat-forming processes are reestablished.	Toutle
K-403,	Reports the results of EDT analysis	Toutle
K-407	Important spring chinook EDT reaches in the Toutle basin are located in the North Fork. Habitat factors affecting these reaches include sediment, temperature, channel stability and habitat diversity (Figure 11). The causes of these impacts are similar to those discussed for fall Chinook.	NF Toutle
E-59	At the North Toutle Hatchery, the adult collection facility is a temporary weir for collecting coho salmon and fall Chinook. The weir is installed and removed annually and only effects fish passage during the time of adult coho and fall Chinook	Toutle Hatchery
E-381	They report land cover data (GIS) and vegetation seral stages.	Toutle
E-395	Chronically low cutthroat escapement at Toutle River Fish Collection Facility (0 to 6 fish annually since 1991)	FCF
E-401	NF Toutle reaches 7 and 12-13 have a high EDT priority ranking for winter steelhead	NF Toutle
E-17	Bear, Hoffstadt, Johnson, Alder, Devils, and Herrington Creeks are examples of tributaries important to coho; coho adults are collected and passed to tributaries above the North Toutle Sediment Retention Dam	Toutle
E-50	The trend in sediment conditions in the mainstem Cowlitz is expected to remain constant in subwatersheds above the confluence with the Toutle, and to degrade over the next 20 years in mainstem reaches downstream of the Toutle.	Cowlitz
E-374	Address Passage and Sedimentation Issues Associated with the Sediment Retention Structure on the North Fork Toutle	SRS
E--18	Reports Cowlitz and N. Toutle River Hatchery rack returns of coho, 1951-2000	Cowlitz and NF Toutle

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	K-407		Sediment is a significant problem for Chinook as it impacts important spawning areas in the mainstem and SF Toutle. Sediment originates from channel as well as upslope sources. Severe sediment aggradation from upstream sources has initiated bank cutting that increases sedimentation from channel sources. Habitat diversity has been reduced by scour or burial of large wood pieces. Loss of channel stability and wood recruitment potential is related to the poor condition of riparian forests.	SF Toutle
	E-374		Manage Forest Lands to Protect and Restore Watershed Processes	Toutle
	E-384		Reports Fall chinook Toutle Hatcheryrack counts, 1951-2000	Toutle
	K-407		Sediment remains in the system from the eruption and continues to be delivered as a result of unstable upslope soils and high road densities. Much of the North Fork basin was heavily roaded and harvested following the 1980 eruption, further increasing sediment and flow problems and slowing recovery	NF Toutle
	E-374		Restore Valley Floodplain Function, Riparian Function and Stream Habitat Diversity	Toutle
Lee	**1996**	**Effects of the eruptions of Mount St. Helens on physical, chemical, and biological characteristics of surface water, ground water, and precipitation in the western United States. USACE Call # - GB 990 .U55 WSP 2438**		
	62		Thorough review of literature up to the time. Many references summarized and cited.	Columbia, Toutle,
	62		Thorough review of literature up to the time. Many references summarized and cited.	Columbia, Toutle,
Lieder	**1989**	**Increased straying by adult steelhead, Salmon gairdneri, following the 1980 eruption of Mount St. Helens. Enivornmental Biology of Fishers 24:219-229.**		
			Returning adults were scarce in the first 3 years after the eruption.... Physical changes to the rivers and to the chemical properties of the water were so great that ... many fish strayed from their river of origin... Estimates of adult steelhead straying from volcanically impacted river increased from 16% preeruption to 45% posteruption.	Toutle
Loch	**1990**	**1989 Toutle River Fish Collection Facility operation and salmonid investigations. WDW Fish Mgmt. Div. Rept. 89-13.**		
	section 2.3.5		Of the 403 coho salmon trucked above the SRS, two coho fallbacks were observed at locations below the SRS and FCF.	FCF, SRS
	section 2.2.1		The inefficiency of the temporary trap in holding fish and poor attraction flow limited capture of winter-run adults / many wild winter-run may have escaped prior to the addition of the weir structure.	FCF
	section 5.0		They report juvenile density data for steelhead, cutthroat, and coho salmon electrofished in several tribs of the Toutle River watershed, 1989.	Toutle

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		section 4.0	They report the results of a creel survey conducted on the South Fork Toutle River to assess angler use and catch rate from wild winter-run steelhead.	SF Toutle
		section 2.3.8	Focused flow at fish entrance at FCF may explain why few winter-run adults entered the FCF in 1989.	FCF
		section 2.3.8	Persistent sediment problems at the FCF / 2-3 meters of sand was deposited / took several months to remove / affected the number of summer steelhead observed.	FCF
		section 2.3.4	It is likely that many cutthroat were able to escape the temporary trap February - June, 1989.	FCF
		section 2.3.1	All wild winter-run steelhead were released 5 km upstream of the FCF into Alder Creek	FCF, NF Toutle
Loch	**1991**	**1990 Toutle River Fish Collection Facility operation and salmonid investigations. WDW Fish Mgmt. Div. Rept. 91-13.**		
		5	Of the 18 winter-run steelhead transported above the SRS in 1989, 11% (2 returnees) were handled again in 1990.	FCF, SRS
		16	They report the results of a creel survey conducted on the South Fork Toutle River to assess angler use and catch rate from wild winter-run steelhead.	SF Toutle
		5	All wild winter-run steelhead were released 5 km upstream of the FCF into Alder Creek	FCF, NF Toutle
		22	There were numerous problems with equipment and resident housing at the FCF in 1990.	FCF
		18	They report juvenile density data for steelhead, cutthroat, and coho salmon electrofished in several tribs of the Toutle River watershed.	Toutle
		15	No steelhead or cutthroat released above the SRS were recovered as fallbacks at the FCF or observed in streams other than their original release site.	FCF, SRS, NF Toutle

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Loch	**1992**	**Toutle River Fish Collection Facility operation and salmonid investigations, 1991. WDW Fish Mgmt. Div. Rept. 92-16.**		
	9	They report tag returns from sport anglers.		Toutle
	2	All wild winter-run steelhead were released into Alder Creek		FCF, SRS
	5	Trapping at the FCF was affected by construction work from May 15 - June 15 and August 14 - September 30.		FCF
	13	They report the results of a creel survey conducted on the South Fork Toutle River to assess angler use and catch rate from wild winter-run steelhead.		SF Toutle
	15	They report juvenile density data for steelhead, cutthroat, and coho salmon electrofished in several tribs of the Toutle River watershed.		Toutle
Loch	**1993**	**Toutle River Fish Collection Facility operation and salmonid investigations, 1992. WDW Fish Mgmt. Div. Rept. 93-5.**		
	14	They report juvenile density data for steelhead, cutthroat, and coho salmon electrofished in several tribs of the Toutle River watershed.		Toutle
	9	They report tag returns from sport anglers.		Toutle
	4	Wild adult winter steelhead were released into Alder Creek, Hoffstadt Creek, and Bear Creek.		FCF, SRS
	13	They report the results of a creel survey conducted on the South Fork Toutle River to assess angler use and catch rate from wild winter-run steelhead.		SF Toutle
Lombard	**1981**	**Channel conditions in the lower Toutle and Cowlitz rivers resulting from the mudflows of May 18, 1980. USACE Call # - QE 523 .S23 C49 1981**		
	C1 (abstract)	The potential exists for unusually high flood levels, up to 10-ft higher than normal, from autumn and winter precipitation. Planned flood-alleviation measures include dredging, additional levees, and sediment-retention structures. A flood-warning system has been established, and the current potential for flooding is being monitored through continued surveillance of the river system.		Toutle, Cowlitz

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Lombard	**1986**	**Channel geometry, flood elevations, and flood maps, lower Toutle and Cowlitz Rivers, Washington, June 1980 to May 1981. Water-Resources Investigations Report 85-4080. Tacoma, WA: U.S. Department of the Interior, Geological Survey. 34 p.**		
	throughout	Report catalogs and documents the conditions of affected lakes and the populations present within them. See table of contents for a list of the surveyed lakes.		Toutle, Cowlitz, Lewis
	1 (abstract)	Periodic river surveys between June 1980 and May 1981 indicate, however, that new sediment is often deposited, sometimes in appreciable amounts, by storm runoff from the mudflow- laden Toutle River basin and erosion of dredged spoil materials. A high flow in December 1980 deposited an average of i0 feet of sediment in the Cowlitz River at Castle		Toutle, Cowlitz
	1 (abstract)	On the basis of backwater analysis of data from a river survey on June 19, 1980, a major flood discharge of 86,500 cubic feet per second would have caused water-surface elevations on the Cowlitz River that are higher than those predicted for the pre-eruption channel by approximately 6.2 feet at Castle Rock, 8 feet at Lexington, and 5.6 feet at Kelso and Longvlew. These predicted water-surface elevations were lowered by 7.8 feet (which is lower than the pre-eruptive elevation), 5 feet, and 4 feet, respectively, when dredging operations, begun in June 1980, were completed on the Cowlitz River in May 1981 by the U.S. Army Corps of Engineers.		Cowlitz, Castle Rock,
Lucas	**1985**	**Recovery of Game Fish Populations Impacted by the May 18, 1980 Eruption of Mount St. Helens. Part I. Recovery of Winter-Run Stealhead in the Toutle River Watershed. Washington Department of Game. Fishery Management Report 85-9A**		
	i (abstract)	High water temperatures and lack of large woody debris are major obstacles to full recovery of winter steelhead populations.		Toutle
	i (abstract)	Hillside erosion, due to a lack of groundcover, contributed to stream bedloads.		Toutle
	i (abstract)	Studies from 1980-1984 monitored recovery of winter steelhead populations in the Toutle. Initially many fish avoided the Toutle, with widespread straying into other Columbia River tributaries. Electrofishing and spawning surveys determined that steelhead populations have rebounded dramatically as the habitat recovered. Flushing of fine sediments from spawning gravels has been rapid in watersheds with narrow floodplains, e.g. the South Fork Toutle and Green River. An average of 705 redds/km were found in the South Fork in 1984. Abundance of yearling and older steelhead in Johnson Creek, a South Toutle tributary, increased ten-fold from 0.01 fish/m2 in 1981 0.10 fish/m2 in 1984.		Toutle
	i (abstract)	The eruption blast destroyed riparian vegetation sending water temperatures soaring to 26 C on some streams.		Toutle

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Lucas	**1986**	**Recovery of Winter-Run Steelhead in the Toutle River Watershed. Washington Department of Game. 1985 Progress Report. Fishery Management Report 86-6**	
	1 (abstract)	A spawning survey of the South Fork Drainage, and to a limited extent the Green River, North Fork, and main Toutle, was completed in 1985. The survey was part of an ongoing effort to monitor recovery of winter steelhead populations in the Toutle River and determine if future spawning escapement in the Toutle will be sufficient to consider a limited harvest fishery.	Toutle
	1 (abstract)	Use of a harvest quota system is evaluated. Under this program, if the South Fork Toutle were opened for a harvest fishery, the number of steelhead creeled would be restricted by issuing a predetermined number of harvest tags.	South Fork Toutle
Major	**2003**	**Clearing Toutle River sediment issue: an op-ed opinion. The Columbian, August 9, 2003.**	
		Upstream migration of the sediment wedge has led to a sharp reduction in the slope of the river valley where the natural channel meets the wedge. Continued sediment delivery from the North Fork Toutle valley will fill that break and smooth the slope; that is how future sediment will be stored. Once the channel slope upstream of the retention structure becomes uniform, more and coarser sediment may bypass the structure, depending upon regrowth of vegetation upstream.	SRS
		The retention structure was designed to trap about 250 million cubic yards of sediment. So far, it has trapped somewhat more than 100 million cubic yards. Thus, storage capacity behind it is not full. However, sediment behind the structure has filled to the level of the spillway, apparently 40 years early, and now about 1 million cubic yards of silt and fine sand bypasses the structure annually.	SRS
		Sediment entering pooled water settles rapidly and commonly deposits progressively in a downstream direction. The SRS pooled some – but not a large body of – water; thus, sediment accumulated closer to the SRS more rapidly than was anticipated. Now it is progressively building a wedge in an upstream direction.	SRS
		The sediment retention structure is still effective; it traps most of the sediment delivered. It's not as effective as it used to be, but the bypassed sediment is not changing downstream channel shapes yet. Corps engineers project that within 20 years enough sand may bypass the structure to raise the Cowlitz River bed. Presently, sediment bypassing the structure poses no flood hazard to downstream communities.	SRS

Author	Year	Title	Page	Comment	Spatial
Major	**2001**	**Evolution and Timing of Suspended-Sediment Transport Following the 1980 Mount St. Helens Eruption, in Proceedings of the Seventh Federal Interagency Sedimentation Conference, March 25 to 29, Reno, Nevada.**			
			1 - 137	After 20 years suspended-sediment yields from some basins remain 10-100 times greater than typical background values. Suspended sediment is transported dominantly by stormflows; more than 50% of the suspended-sediment load is transported in 1 to 4 weeks each year. Very large floods have transported as much as 50% of the annual suspended-sediment load in a single day from some basins. Although large stormflows can transport quantitatively significant volumes of sediment, the majority of the annual suspended-sediment load is transported by stormflows that have return intervals of less than 1.5 years. Discharges smaller than mean annual flow transport #10% of the annual suspended-sediment load. Two decades of monitoring suspended-sediment discharges and channel geometry changes in the aftermath of the catastrophic Mount St. Helens eruption demonstrate the long-term instability of eruption-generated detritus and show that geomorphically significant evolution of disturbed watershed generally proceeds under commonplace hydrologic conditions.	Toutle
Major	**2004**	**Posteruption suspended sediment transport at Mount St. Helens: Decadal-scale relationships with landscape adjustments and river discharges, J. Geophys. Res., 109, F01002, doi:10.1029/2002JF000010.**			
				This paper also provides data on river discharge and suspended sediment concentrations.	Toutle
			1	Discharges smaller than mean annual flows generally have transported <5%, but locally ~15%, of the annual suspended sediment loads, and infrequent ($p < 0.01$), large floods have transported as much as 50% of the annual suspended sediment loads in a single day. However, moderate-magnitude discharges (those greater than mean annual flows but less than 2-year floods) have transported the greatest amounts of sediment from all disturbance zones. Such discharges have transported, on average, 60% to ~95% of the annual suspended sediment loads, usually within cumulative periods of 1–3 weeks each year. Although small-magnitude and large magnitude discharges have locally and episodically transported considerable amounts of suspended sediment, there has not been any notable change in the overall nature of the effective discharges; moderate-magnitude flows have been the predominant discharges responsible for transporting the majority of suspended sediment during 20 years of posteruption landscape adjustment.	Toutle

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18	Although small-magnitude discharges may have been important sediment-transporting flows during the earliest phases of response to the disturbances, posteruption sediment redistribution \has occurred largely by moderate, albeit relatively frequent, discharges, despite the cataclysmic nature of the disturbances and the local and episodic importance of sediment transport by small-magnitude and large-magnitude discharges.	Toutle
2	The eruption began with a colossal failure of the volcano's north flank [Voight, 1981]. A consequent debris avalanche deposited 2.5 km3 of poorly sorted rock, soil, ice, and organic debris in the upper North Fork Toutle River valley [Glicken, 1998], buried 60 km2 of the valley to a mean depth of 45 m, and disrupted the watershed's drainage pattern [Lehre et al., 1983; Janda et al., 1984]. A synchronous directed blast, a type of highly mobile pyroclastic surge, ravaged ~600 km2 of rugged terrain and blanketed the landscape with up to 1 m of gravel to silt tephra [Hoblitt et al., 1981; Waitt, 1981]. Blast deposits on slopes exceeding approx. 35 degrees C remobilized spontaneously and generated secondary pyroclastic flows that deposited local valley fill as thick as 10 m [Hoblitt et al., 1981; Brantley and Waitt, 1988].	Toutle
3	Minor explosions from a lava dome that grew within the crater of Mount St. Helens subsequent to the 1980 eruptions triggered a large debris flows, in March 1982, which discharged ~3.5 Mt of sediment from the Toutle River watershed [Dinehart, 1986, 1999].	Toutle
3	Local liquefaction of the debris avalanche deposit, and groundwater seepage that filled and breached depressions on the deposit surface, spawned the North Fork Toutle River debris flow [Janda et al., 1981; Fairchild, 1987]. That debris flow entrained additional sediment and initiated drainage integration across the distal surface of the avalanche deposit, flowed more than 100 km, and deposited tens to hundreds of centimeters of gravelly sand along the valleys of the North Fork Toutle and distal Toutle rivers.	Toutle

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	4	Since November 1987 (water year 1988), the SRS has impounded most of the sediment eroded from the debris avalanche deposit and upper North Fork Toutle River valley. By March 1998, the sediment fill behind the SRS reached the level of the spillway crest; between 1998 and 2002, ~1 Mt of silt and fine sand bypassed the structure annually.		Toutle
Major	**2000**	**Sediment Yield Following Severe Volcanic Disturbance - A two-decade perspective from Mount St. Helens, Geology; September 2000; v. 28; no. 9; p. 819-822; 3 figures.**		
	819 (abstract)	Posteruption sediment yields can exceed preeruption yields by several orders of magnitude. Annual suspended-sediment yields following the catastrophic 1980 Mount St. Helens eruption were as much as 500 times greater than typical background level, and they generally declined nonlinearly for more than a decade. Although sediment yields responded primarily to type and degree of disturbance, streamflow fluctuations significantly affected sediment-yield trends. Consecutive years (1995–1999) of above-average discharge reversed the nonlinear decline and rejuvenated yields to average values measured within a few years of the eruption. After 20 yr, the average annual suspended-sediment yield from the 1980 debris-avalanche deposit remains 100 times (104 Mg [megagrams]/km2) above typical background level (~102 Mg/km2).		Toutle
Martin	**1986**	**Influence of riparian vegetation on posteruption survival of coho salmon fingerlings on the west-side streams of Mount St. Helens, Washington. North American Journal of Fisheries Management 6: 1-8.**		
	1 (abstract)	The researchers examined factors related to juvenile coho salmon disappearance during the summer and winter months of 1981 and 1982. They found correlations between the survival of anadromous fish, instream vegetative debris cover, and water temperature.		Toutle
	1 (abstract)	Recovery of riparian vegetation would reduce stream temperatures and cause debris to be retained. Tree growth data suggest trees will be tall enough to effectively shade the third- and fourth-order streams in 5-20 years, and that it will be 50-75 years before the trees are large enough to create organic debris structures when they fall into a stream. These results imply that management activities that promote large organic debris will enhance fish survival.		Toutle
Martin	**1984**	**The effects of the Mount St. Helens eruption on salmon populations and habitat of the Toutle River. Report FRI-UW-8412. UW Call # QL638S2E381984. There is also a version of this report from the Mount St. Helens Effects on Water Resources Conference of Oct. 1981.**		

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xi (from	Juvenile coho mortality during winter ranged from 62-83% in unaffected streams and 82-100% in affected streams. Mortality increased with increases in severity of impact and was associated with channel stability, suspended sediment, and the amount of cover provided by large organic debris (R2 = 0.57).	Toutle
xii (from	Tree planting, riparian timber management, and artificial inputs of large organic debris could accelerate habitat recovery.	Toutle
xii (from	Coho survival during smolt outmigration was in excess of 42% for a 46km reach of the Toutle River. Smolt survival for the future is optimistic if suspended levels are lower than 5,000 mg/l during the spring outmigration period.	Toutle
xii (from	An integrated management approach of a hatchery stock operation that compliments wild stock production would make the greatest use of natural habitat and accelerated stock recovery.	Toutle
xi (from	Adult salmon spawned in unstable volcanic substrates with average concentrations of fine particles (<0.850 mm) ranging from 11.2% to 36.0% in 1981 and from 11.2% to 33.5% in 1982. Survival of eggs to hatching stage in volcanic substrate ranged from 50% to 95%. Successful reproduction observed in impacted streams was attributed to temporary groundwater upwelling.	Toutle
xii (from	The lack of instream cover provided by large organic debris will be the limiting factor for complete habitat recovery in the Toutle watershed.	Toutle
xi (from	High concentrations of suspended sediment caused many adult spawners to avoid the Toutle River in 1980 and 1981, and instead return to the upper Cowlitz River and Kalama River.	Toutle, Cowlitz Kalama
xi (from	Old tributary channels buried by the adjacent river mudflow have degraded to near pre-eruption levels and are beginning to develop channel morphology suitable for fish rearing.	Toutle
xi (from	Small 3rd and 4th order tributaries without riparian vegetation would require riparian trees at least 4.2 meters tall to provide enough shade to reduce summer water temperatures to pre-eruption levels.	Toutle
xi (from	Adult salmon and steelhead that returned to the Toutle River were observed spawning in most tributaries formerly utilized before the eruption.	
xii (from	Sediment problems and channel instability on the debris avalanche are expected to diminish in 30 to 35 years.	Toutle
xii (from	Regenerating riparian trees would require 50-75 years to become large enough to provide inputs of large organic debris (25-35 cm) for tributary streams.	Toutle

McIntosh 1995 Summary report for Bureau of Fisheries stream habitat surveys : Cowlitz River Basin, 1934-1942. USACE Call # - QH 541.5 .S7 M352 1995

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	Table of		The document contains habitat surveys for Toutle R., Outlet Ck., Silver Lk., S. Fk. Toutle R., Bear Ck., Trouble Ck., N. Fk. Toutle R., Green R., Devil's Ck., Cascade Ck., Elk Ck., Schultz Ck., Miners Ck., Alder Ck., Hoffstadt Ck., Bear Ck., Jackson Ck., Elk Ck., Mirada Ck., Castle Ck., Coldwater Ck., S. Fk. Coldwater Ck., Studebaker Ck., and Spirit Lake.	Toutle, Cowlitz
	i		This document contains summary reports of stream habitat surveys, conducted in the Cowlitz River basin, by the Bureau of Fisheries (now NMFS) from 1938-1942. These surveys were part of a larger project to survey streams in the Columbia River basin that provided, or had provided, spawning and rearing habitat for salmon and steelhead. The purpose of the survey was "to determine the present condition of the various tributaries with respect to their availability and usefulness for the migration, breeding, and rearing of migratory fishes".	Toutle, Cowlitz
Miller	**2004**	**Letter to Krystyna Wolniakowski, National Fish and Wildlife Foundation, supporting a Sustainable Fisheries Foundation Proposal for Allowing the Fish Trucks to Reach the North Fork Just Above the SRS.**		
			Good numbers of young salmon (have not been seen) coming out of the upper drainage because the adults have a hard time of it. The long truck ride…they are under a lot of stress. Then they are put in either Alder or Hoffstadt Creeks, neither of which may be where they were originally headed.	NF Toutle
			Allow the fish trucks to reach the North Fork just above the	NF Toutle
Ogden	**1983**	**Cowlitz River sediment sump study. USACE Call # - TC 175.2 .O32 1983**		
	1		This report is in response to ongoing concern of the U.S. Army Corps of Engineers, Portland District, regarding the continued movement of bedload sediments out of the Cowlitz and Toutle River systems. The report's overall objective is to provide recommendations regarding the use of dredged sumps to reduce the quantity of sediment entering the Columbia River via the Cowlitz-Toutle waterways.	Cowlitz, Toutle

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Olds	**2002**	**Fisheries Studies at the Sediment Retention Structure on the North Fork Toutle River 1993, 2001, 2002. Olympia, WA: Washington Department of Fish and Wildlife. Prepared for the United States Army Corps of Engineers, Portland District. Contract No. 36001648**	
	23	The cumulative effect of smolts passing both the SRS and FCF, not including transport and handling, was 22%. This indicates that 22% of wild smolts from upstream SRS are injured passing the SRS and FCF during emigration.	SRS
	31	Actions that reduce Spillway water velocities or suspended sediment need to be taken due to smolt passage impact and the conservation status of wild salmonids populations upstream of the SRS.	SRS
	30	Histology reported that gill tissues from all groups of fish were normal, showing few pathological changes.	FCF, SRS
	23	Holding smolts 160 hours post treatment shows that treatments (passing spillway and FCF) did not appear to effect smolt survival in the short term. All but one type of injury types healed, or was advanced in the healing process, after 160 hours post treatment.	FCF, SRS
	27	The shallow south side of the Spillway crest may present a unique injury hazard for smolts at instream flows greater than 872 cfs.	SRS
	20	While many smolts that passed the spillway in 2001 had dorsal scrapes between the head and dorsal fin, no internal damage due to these scrapes was found.	SRS
	20	A sample of 26 smolts that passed the through both the spillway and the FCF were held for 160 hours at the hatchery to help determine short term impacts. After 160 hours injuries were healing as expected and there was no mortality.	FCF, SRS
	23	Outlet Work Pool water quality control group had 1% mortality (3 smolts) over 40 days of holding. The group was in vigorous health upon release at the end of holding. This result indicates the NF Toutle water, at low velocity and suspended sediment concentration, does not threaten coho salmon smolt life in the short term.	FCF, SRS

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			27	This study used hatchery fish and therefore likely presents a conservative estimate of SRS wild coho salmon smolt passage impact. While NF Hatchery fish are reared under relatively stable conditions, including low water velocity, while wild coho salmon observed rearing in tribs above the SRS in 2001 preferred areas of moderate to high water velocities. Wild fish are hence conditioned to withstand a higher level of exercise. In addition, wild smolt survival to the adult lifestage is thought to be higher than hatchery smolt to adult survival.	FCF, SRS, upper NF
			29	While passage impacts don't appear to affect short term smolt survival, adult returns from the 1993 study show that SRS passing smolt survival was lower than control smolt survival under tested conditions.	SRS
			27	Volitional release records from the NF Toutle Hatchery show a strong preference for coho to out migrate after dark. Smolts prefer to migrate at night but will migrate during the day light in turbid water. Wild NF Toutle smolts are exposed to continuous high turbidities in the NF Toutle River.	FCF, SRS, upper NF
			10	Preferred timing for NF Toutle smolts to pass the SRS is 30 days, April 20 - May 20	SRS
Olds	**2004**	**Letter to Krystyna Wolniakowski, National Fish and Wildlife Foundation, supporting a Sustainable Fisheries Foundation Proposal for Construction of a FCF Tank Truck Access and Fish Release Site.**			
				Hoffstadt and Alder Creeks are the only two upper North Fork tributaries that trucks can currently reach to release fish.	NF Toutle
				Modeling studies by the ACOE demonstrate that sediment loading will continue to impact upper NF Toutle River fish populations over the next several decades.	NF Toutle
				Construction of a FCF tank truck access and fish release site would greatly facilitate fish passage into the NF Toutle River.	NF Toutle
				Fish are released in Hoffstadt Creek several miles upstream of the anadromous zone. Once released, fish must find their way downstream through numerous obstacles before returning to spawning grounds.	NF Toutle
				Continued sediment loading and the resulting changes in river geomorphology will prevent truck access to key tributaries and cause the FCF to fail on a more frequent basis.	NF Toutle

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Pacific	**1989**	**Mount St. Helens sediment retention structure, North Fork Toutle River, Cowlitz County: trash handling system. USACE Call # - TC 425 .T6 M68 1989**	
	1-1	Report discusses the impact of trash removal alternatives (removal of floating debris) on fish migration. Fish migration is considered only for fingerlings migrating downstream.	SRS
	1-1	The purpose of this report is to present pertinent information on debris handling systems, including information of quantities, containment, removal and disposal.	SRS
Phinney	**1981**	**Overview of the Effects of the Mount St. Helens Eruption on Salmon Populations. In, Mount St. Helens, One Year Later, S.A.C. Keller, ed. USACE Call # - QE 523 .S23 M68 1981. There is also a version of this report in Conference on Mount St. Heles - Effects on water resources, Jantzen Beach, Oregon 1981, Proceedings: Pullman, Washington, State of Washington Water Research Center, Washington State University, and the University of Washington, Report No. 41, p. 293-299.**	
	throughout	Detailed account of the immediate, intermediate-term, and long-term effects of the eruption on salmon populations	Toutle, Cowlitz
	throughout	The majority of the effects on salmon populations have to due with increased sediment levels, as well as response actions to the sediment problems.	Toutle, Cowlitz
Redding	**1982**	**Mount St. Helens ash causes sublethal stress responses in steelhead trout. Pages 300-307 in Proceedings from the Conference, Mount St. Helens: Effects on Water Resources. Report Number 41. Washington Water Research Center, Washington State University, Pullman, Washington, USA**	
		Exposure of juvenile steelhead to relatively low (500 mg/l) and high (2000 to 3000 mg/l) levels of Mt. St. Helens ash for 48 hours found fish were able to tolerate this relatively short exposure to volcanic sediment without exhibiting prolonged physiological stress responses.	Toutle, Cowlitz
Reebs	**2006**	**Lou Reebs email "SRS Sediment Trapping Suggestions" dated 10.14.2006**	
		Construct a low sediment barrier immediately upstream of the SRS to encourage sediment accumulations in the middle of the valley. This would stimulate tapering sediment gradients towards the river banks where low flows would gravitate. This would minimize the present excessive erosion of high flow sediment deposits by intricately braided meandering rivulets, during low flows, which have a devastating effect on the downstream habitat.	SRS
Reebs	**2005**	**Potential Mt. St. Helens habitat restoration projects -- Lou's ideas 6.15.05**	
		Funds would be requested to document the N1 and SRS COE projects from a results viewpoint with extensive use of visuals. Appropriate references from the COE reports, including potential future actions, would be included. The various property ownerships and interagency agreements would also be documented. It would conclude with suggestions for sediment control and associated agency responsibilities. It would also suggest that an overall manager is appointed to direct and monitor the various sedimentation issues.	SRS

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		…the study would show from a reality viewpoint that the SRS is full. The COE should keep their spillway fish passage commitments. The N1 spillway should be left as is to hold back sediments. The SRS mud plane should be stabilized using large woody debris from Spirit Lake...	SRS
		Project "B" Solicit funding for a short log boom. This log boom would be connected to the existing log boom near the end closest to the SRS spillway and it would extend diagonally upstream to the southerly end of the rock outcropping located about one quarter mile upstream from the south end of the SRS structure. This log boom would trap sediments along its southerly edge near the existing vegetated sediments and further stabilize this area. The northerly edge of this boom would establish a boundary for flows from Alder Creek and Deer Creek, which currently flow along the south side of the valley. Alder Creek enters the valley about one mile upstream from the suggested log boom terminus and Deer Creek enters the valley about two miles further upstream. They are both former WDFW fish rearing streams. ... If this project is implemented it would definitely help direct adults destined to Alder Creek, in my opinion.	SRS
		Project "C" Secure funding for an appropriate track mounted amphibious vehicle for use constructing and monitoring Project "A", which could also be used to transport adult salmonids from the trap to a release site along the Project "B" log boom.	SRS
		Project "A" Solicit SRS sediment plane monitoring. Install grid of poly pipes at about 200 feet spacing each way through the sediment deposits for about one mile upstream of the SRS. I suggest 10 ft lengths of one-inch dam pipes with black electrical tape marking at one ft intervals for five feet on one end. I would then insert pipes into the sediment plane until the marked ends protruded five feet.	SRS
Reebs	**2005**	**SRS Sediment Trap Sketch and Letter with design suggestions. Letter in reference to concerns about logs floating and facilitating sediments escaping through the trap.**	
		…anchor the logs to keep them in contact with the underlying sediments…may be better to encourage them to float and simply attach a skirt to the inside of the log boom which would prevent the sediments from escaping. This would potentially increase the capacity of the trap as the upstream gradient.	NF Toutle
Rosenfeld	**1983**	**Evolution of a drainage network : remote sensing analysis of the North Fork Toutle River, Mount St. Helens, Washington. USACE Call # - GB 906 .R67 1983**	
	I	This project provided aerial surveillance, mapping, and evaluation of the hydrologic conditions in the upper reaches of the North Fork Toutle River valley from October 1981 until January 1983. The purpose of the work was to assess the rate and mode of erosional and depositional development, and evaluate the potential for the occurrence of catastrophic events.	NF Toutle

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Seiler	**1992**	**Evaluation of Downstream Migration Passage Through the Sediment Retention Structure North Fork Toutle River 1991. Washington Dept. of Fisheries Progress Report 297.**	
		Found that peak out migration for wild coho occurred May 4 with only low numbers leaving in April and June	Toutle
		Reports that transport and handling reduced survival 24.9% for coho smolts.	FCF, SRS, upper North
		Good study done on smolt passage, but preformed before the SRS had filled and thus all the data are for passage through the SRS outlet works, not the spillway.	SRS
Shaw	**1980**	**Upstream Fisheries and Wildlife, from On the Effects of the Mount St. Helens Eruption on Water Resources. Vancouver, Washinton. June 12, 1980.**	
	43	The Fish and Wildlife Service is not presently directing any efforts on evaluating impacts of the eruption on fishery resources within the immediate area of the mountain. Present evidence indicates that aquatic resources in the Toutle and lower Cowlitz Rivers have been devastated.	Toutle, Cowlitz
	43	The Service is focusing efforts on assisting the Corps of Engineers in locating sediment disposal areas. Emphasis is placed on identifying spoil sites where the least long-term damage to wetlands will occur. Habitat losses are being documented in the spoil sites and the information will be used in developing rehabilitation programs.	Toutle, Cowlitz,
Steward	**2004**	**Letter to Gary Wade, Lower Columbia Fish Recovery Board regarding Letter of Intent to LCFRB: Establish Fish Passage through Spillway of Sediment Retention Structure on the North Fork Toutle River.**	
		Suitable access for releasing fish into the North Fork and Hoffstadt and Alder Creeks is difficult due to unstable conditions upstream of the SRS.	NF Toutle
		Due to the cost of operating the FCF and questions regarding the fate of fish transported and released above the SRS, it would be better to facilitate volitional upstream passage through the spillway, provided that an economical and biological satisfactory engineering solution can be found.	NF Toutle
		The Fish Collection Facility is frequently incapacitated by sediment and debris and is in a serious state of disrepair. Although adult collection efficiency has not been determined, it is thought to be poor.	NF Toutle
		The USACOE has shown that future SRS impacts to the upper North Fork Toutle River will result in further loss of FCF Tank Truck access and increased failure rates in FCF operations due to increases in sediment and debris flows.	NF Toutle
		Propose to restore fish passage through the Sediment Retention Structure on the NF Toutle River…	NF Toutle
		North Fork Toutle populations of coho salmon, steelhead and sea-run cutthroat are depressed, and soon may be lost altogether if better passage to spawning grounds is not provided.	NF Toutle

Author	Year	Title	
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	2004	**Letter to Krystyna Wolniakowski National Fish and Wildlife Foundation, supporting the construction of an access road along the face of the SRS.**	
		A road leading from the dam would remain serviceable under all but the highest flows, and will not be obliterated or made impassable by sediment.	NF Toutle
		An access road is urgently needed for two important reasons: the amount of woody debris floating down the channel can be expected to increase, requiring removal to prevent clogging of the spillway and concomitant flooding; it would provide a	NF Toutle
		Construction of a short road segment along the face of the SRS on the NF Toutle River…enabling vehicle access to the river channel and the SRS spillway, over which water now flows.	NF Toutle
Steward	**2004**	**National Fish and Wildlife Foundation Preproposal; NF Toutle Salmonid Trap and Haul Release Relocation 2004**	
		Salmonid populations in the NF Toutle River will benefit from the relocation of the point of release for adult salmonids collected and transported upstream of the Sediment Retention	NF Toutle
		The purpose of this project is to construct a short section of road at the face of the SRS that would allow fish to be released quickly and efficiently into the upper NF subbasin.	NF Toutle
		The objectives of this project are to reduce trap and haul mortality by reducing the time, distance and complexity of hauling and release operations; to allow adult salmonids to naturally select their stream of origin rather than forcing them to seek out available habitat near the current release locations; to improve smolt passage by minimizing smolt damage as they traverse the spillway lip; and to provide construction access for future adult fish passage projects on the currently impassable SRS spillway.	NF Toutle
		The project will require laying surplus traffic dividers on their sides end to end around the south spillway abutment to act as curbing. The traffic dividers will be laid 15 feet away from the abutment face, and will extend to the stream channel immediately upstream of the concrete surfaced spillway lip. The wider base sections of the traffic dividers will be positioned into the flow to provide refuge for migrating smolts during moderate to high flows. The space between the curbing and abutment will be filled with rock to restore vehicle access to the spillway.	NF Toutle
		The proposed project will create an efficient, easily accessed, and permanent location for releasing upriver bound steelhead, coho salmon and cutthroat trout.	NF Toutle
		Restoring salmonid runs in the NF Toutle is a necessary component of the overall goal of restoring salmonid runs to their historic range in the Cowlitz River watershed.	NF Toutle

Author	**Year**	**Title**	
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Stober	**1981**	**Effects of suspended volcanic sediment on coho and chinook salmon in the Toutle and Cowlitz Rivers. Technical completion report; contract Number 14-34-0001-1417. Seattle, WA: University of Washington, College of Fisheries, Fisheries Research Institute. 171 p. There area also versions of this report in Eos (American Geophysical Union Transactions). 61(46): 956. and in Mount St. Helens Five Years Later, ed. S.A.C. Keller.**	
		The tolerance of coho and Chinook salmon to suspended volcanic sediment was determined by live-box and static laboratory bioassays. Histological analysis of the gill tissue from both field and laboratory tested salmon did not show a suspended sediment effect.	Cowlitz, Toutle
United		**Cowlitz River basin : water year hydrologic summary. USACE Call # - GB 1225 .W2 C68**	
	throughout	Hydrologic Summary reports are available in the USACE Tech. Library for many years (1989-1993, 1997, 2001). A recent Hydrologic Summary report (2005) was thoroughly reviewed (see Ref_ID 19 for detailed comments). Hydrologic Summaries contain information regarding sediment sampling, cross-section surveys, SRS operations, sediment deposition (esp. yearly numbers upstream of SRS), and the outlets and spillway.	SRS, Toutle, Lower
United	**2005**	**Cowlitz River Basin Hydrologic Summary Water Years 2003-2004. USACE, Portland District.**	
		Reports annual deposition upstream of the SRS and suspended sediment transport past Tower Road.	NF Toutle
		It is estimated that a net deposition of 0.7 million cubic yards occurred above the SRS in WY 2004	NF Toutle
		Other factors that can influence sedimentation processes and the amount of deposition being the SRS include: landslide activity, headcutting, and stream migration into sediment source areas,.	NF Toutle
		Reports daily mean water and sediment discharge for WY 2004 at Toutle River at Tower Road.	Toutle
		Reports annual sediment discharge for WY's 1982-2004.	Toutle
		The total estimated sediment volume trapped behind the SRS is 102.3 million cubic yards.	NF Toutle
		Sedimentation processes are directly related to hydrologic conditions / sedimentation processes are also related to high flow events	NF Toutle
		There is some evidence that stream movement in the area upstream of the old N-1 structure about 5 miles upstream of the SRS is cutting into old mudflow and N-1 sediment deposits. This could contribute to additional deposition immediately upstream of the SRS.	NF Toutle

Author	Year	Title / Page	Comment	Spatial
			Based on the gage data, it appears that there was no significant change from WY 2003 to WY 2004 in the channel capacity of the lower Cowlitz River and the level of protection at the levees is still within the required limit as of the end of WY 2004.	Lower Cowlitz
			Reports annual profiles of the average elevation of the depositional zone upstream of the SRS	NF Toutle
			All outflow from the SRS in WY 2004 went through the	SRS
			Reports WY 2003 - 2004 change in bathymetry in the sediment plane behind the SRS	NF Toutle
			Total suspended sediment discharge for WY 2004 water year was 1.28 million tons at the Toutle River at Tower Road station, and 0.18 million tons at the South Fork Toutle River at	Toutle
United	**1985**	**Cowlitz-Toutle dredging report. USACE Call # - TC 187 .C68 1985**		
		i (preface)	Continued sediment inflow resulting from the 1980 Mt. St. Helens eruption has resulted in lower flood protection levels. One solution to increased flood protection and sedimentation control in the affected areas is a long-term dredging plan for the Cowlitz and lower Toutle Rivers, which would also consider dredging at the confluence of the Columbia and Cowlitz Rivers. This report is the result of efforts to identify the optimum dredging and disposal plan for a 50-year period to reduce the impact of sedimentation on the Cowlitz and Toutle River Basins.	Columbia, Cowlitz,
United	**1984**	**Interim alternative action plan : Cowlitz & Toutle Rivers, Washington.. USACE Call # - TC 530 .I57 1984**		
		executive	The Supplemental Appropriations Act of 1983 (PL 98-63) authorizes the Corps of Engineers to maintain flood control measures on the Cowlitz and Toutle Rivers, Washington, until such time as permanent solutions and measures for flood control and navigation are fully implemented. This report evaluates the various flood control alternatives available to comply with this directive, and provides the most cost effective alternative of those examined.	Cowlitz, Toutle
United	**2002**	**Mount St. Helens engineering reanalysis : hydrologic, hydraulics, sedimentation and risk analysis. Design documentation report. USACE Call # - TC 202 .P67 M68 DDR 2002**		
		executive	Between Nov. 1997 and March 1998 the pool of water formed by the SRS filled to the elevation of the spillway crest with sediment. At that point about 1/3 of the SRS's sediment storage capacity was depleted. With the pool of water filled with sediment, some fine sediment began to pass the SRS as anticipated. As time passes, the slope of the sediment deposits upstream of the SRS will gradually increase and larger and larger particles will pass the structure. If the particles that pass are too large for the Cowlitz River to readily transport or if so much sediment passes that the transport capacity of the Cowlitz River is over-whelmed, then deposits will accumulate in the Cowlitz River and flood protection will be impacted.	SRS, Toutle, Cowlitz

Author	Year	Title	
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	executive	The purposes of this study were to (1) determine the risk of flooding at the lower Cowlitz River damage reaches as the project operation changes with time and (2) develop basic physical and hydraulic data required for further alternative analyses.	SRS, Toutle, Cowlitz
	executive	The study results indicate that the level of flood protection at the Castle Rock, Lexington, and Kelso levees will drop below Congressionally authorized levels between 2020-2025 and the level at the Longview levee will drop below the Congressionally authorized level between 2030-2035.	SRS, Toutle, Cowlitz
United	**1980**	**Mount St. Helens eruption : impacts on the Toutle, Cowlitz, and Columbia River system. USACE Call # - GB 1225 .W2 M68 1980 OVERSIZE**	
		Reports Cowlitz and Columbia Rivers sediment sampling and analyses	
United	**1981**	**Mount St. Helens eruption : long-term program for Cowlitz and Toutle River Basins, Cowlitz County, Washington.. USACE Call # - TC 424 .W2 M686 1981**	
	synopsis	This report provides direction for future flood damage reduction and restoration activities in the Cowlitz and Toutle River Basins. This long-term program is necessary to insure that flood reduction efforts, are not terminated while a need still	Columbia, Cowlitz
United	**1985**	**Mount St. Helens National Volcanic Monument : final environmental impact statement comprehensive management plan.. USACE Call # - TD 194.56 .W22 M68 1985**	
	Record of	This report documents the decision to select Alternative D (East and Westside Moderate Development - Modified) as the Comprehensive Management Plan for the Mount St. Helens National Volcanic Monument.	Volcanic Monument
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United	**1997**	**Mount St. Helens protective works, Mount St. Helens, Washington : Spirit Lake tunnel, Coldwater Lake, South Castle Lake : periodic inspection report. USACE Call # - TC 550 .P67 S6 PIR**	
	throughout	Periodic inspections of the Spirit Lake tunnel and the outlet channels at Coldwater and South Castle lakes were conducted from 1987-1996. Army Corps Periodic Inspection Reports were completed following each inspection. The 10 report series is available in the USACE Tech. Library.	Spirit, Coldwater South

Author	**Year**	**Title**	
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United	**1993**	**Mount St. Helens sediment control, Cowlitz and Toutle Rivers, Washington. Design memorandum no. 17, sediment retention structure master plan for resource use. USACE Call # - TC 202 .P67 M68 DM 17 OVERSIZE**	
	2-16 (section	Document includes analyses concerning pre-eruption fisheries, fish rearing, commercial value, salmon stocking numbers, post-eruption fish habitat, redd densities (Alder, Elk, Studebaker, SF Toutle, Green), estimated winter steelhead spawning escapement 1987, post-eruption fisheries management, and potential fisheries management.	Toutle
	4-1 (section	The DM contains some good maps and inventories of natural resources in the project area. A more intensive review is recommended.	NF Toutle
United	**1987**	**Mount St. Helens sediment control, Cowlitz, and Toutle Rivers, Washington. Design memorandum no. 10, sediment retention structure fish collection facility. USACE Call # - TC 202 .P67 M68 DM 10**	
	i (syllabus)	This design memorandum presents the description, criteria, and design of the fish collection facility for the sediment retention structure, as well as discusses interim fish collection.	FCF, SRS
	i (syllabus)	The fish collection facility is required as mitigation for blocking upstream fish passage at the sediment retention structure.	FCF, SRS
	Encl 2	SRS construction activities first blocked fish in March or April 1987.	SRS
United	**1986**	**Mount St. Helens sediment control, Cowlitz, and Toutle Rivers, Washington. Design memorandum no. 11, sediment retention structure sediment ranges. USACE Call # - TC 202 .P67 M68 DM 11**	
	throughout	This DM presents sediment ranges (survey cross-sections near impoundment, to measure deposition and erosion) and sediment monitoring plans and costs.	SRS, immediately
United	**1986**	**Mount St. Helens sediment control, Cowlitz, and Toutle Rivers, Washington. Design memorandum no. 12, sediment retention structure instrumentation, inspection, and evaluation. USACE Call # - TC 202 .P67 M68 DM 12**	
	syllabus	DM 12 outlines (1) the type, location, and number of instruments to be installed at the Toutle River SRS; (2) a program for inspection and evaluating the performance of completed structures at the SRS; and (3) schedules for reading installed instruments and performing periodic inspections.	SRS

Author	Year	Title	
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United	**1988**	**Mount St. Helens sediment control, Cowlitz, and Toutle Rivers, Washington. Design memorandum no. 13, sediment retention structure initial filling plan. USACE Call # - TC 202 .P67 M68 DM 13**	
	syllabus	DM 13 documents the plan for surveillance during the initial filling of the SRS reservoir. Surveillance during the first significant drop in pool elevation after filling is also covered.	SRS
United	**1988**	**Mount St. Helens sediment control, Cowlitz, and Toutle Rivers, Washington. Design memorandum no. 16, McCorkle Creek pump station addition. USACE Call # - TC 202 .P67 M68 DM 16**	
	syllabus	DM 16 describes the proposed plan to augment the pumping capacity at the McCorkle Creek Pump Station, Lexington, Washington.	Lexington
United	**1986**	**Mount St. Helens sediment control, Cowlitz, and Toutle Rivers, Washington. Design memorandum no. 8, sediment retention structure embankment and foundation excavation. USACE Call # - TC 202 .P67 M68 DM 8**	
	throughout	DM 8 discusses embankment and foundation excavation operations for the SRS	SRS
United	**1987**	**Mount St. Helens sediment control, Cowlitz, and Toutle Rivers, Washington. Design memorandum no. 9, sediment retention structure spillway and outlet works. USACE Call # - TC 202 .P67 M68 DM 9**	
	i (synopsis)	The estimated cost of the embankment dam, spillway, outlet works, and project roads in $68,500,000. The project construction time is 3 years with sediment storing capacity available in October 1987.	SRS
	i (synopsis)	DM 9 presents the description, criteria, and design of the spillway and outlet works for the SRS. Major emphasis is given to the structural, hydraulic, electrical, and mechanical designs and to future operation and maintenance of the spillway and outlet works.	SRS
United	**1991**	**Mount St. Helens sediment retention structure, North Fork Toutle River, Washington : dam, spillway, outlet works : periodic inspection report. USACE Call # - TC 550 .P67 M68 PIR**	
	throughout	Periodic inspections of the SRS Dam Spillway Outlet Works were conducted during 1991-2003 and likely before. Army Corps Periodic Inspection Reports were completed following these inspections. The report series is available in the USACE Tech. Library, however, some documents were not available at the library at the time of research. The next inspection in scheduled for Sept. 2007. The first flows over the spillway occurred in Nov. 1995.	SRS

Author	Year	Title	
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United	**1982**	**Mount St. Helens, Cowlitz and Toutle Rivers sedimentation study, 1980-82. . USACE Call # - QE 581 .M68 1982**	
	vii (executive	Study of sedimentation problems in the Cowlitz River below the Toutle confluence, where the potential for economic loss due to flooding was greatest. The present report id preliminary and contains data and analyses of sediment transport and deposition, computation of water surface profiles, and documentation of changes in the debris avalanche and the subsequent effects seen in the lower Toutle and Cowlitz Rivers	Toutle, Cowlitz
United	**1984**	**Mount St. Helens, Cowlitz and Toutle Rivers sedimentation study/1984 update. USACE Call # - QE 581 .M68 1984**	
	1	This report documents the sediment processes that have occurred in the Toutle/Cowlitz/Columbia river system since the eruption, and forecasts future sediment movement.	Toutle, Cowlitz
United	**1985**	**Mount St. Helens, Washington, decision document : Toutle, Cowlitz and Columbia Rivers. USACE Call # - TC 530 .U541 1985**	
	Toutle,	[The recommended plan] is the National Economic Development (NED) plan, representing the program which will produce the greatest net economic benefits among those considered. In general, its social and physical environmental effects are considerably lower than any management strategy which depends principally on dredging. While requiring mitigation for fish runs into the Upper North Fork Toutle River, this plan improves water quality and reduces environmental impacts everywhere downstream from its location. Because much of the sediment will be retained behind the structure, this program will avoid substantial downstream disposal site mitigation.	syllabus
	syllabus	This report analyzes management strategies for dealing with Mount St. Helens- related sedimentation and resultant flooding in the Toutle/Cowlitz/Columbia river systems. Measures considered include a single sediment retention structure constructed in one stage (SRS) or multiple stages (MSRS), dredging, and levee raises at lower Cowlitz River Valley communities.	Toutle, Cowlitz
	syllabus	[The recommended plan] is the National Economic Development (NED) plan, representing the program which will produce the greatest net economic benefits among those considered. In general, its social and physical environmental effects are considerably lower than any management strategy which depends principally on dredging. While requiring mitigation for fish runs into the Upper North Fork Toutle River, this plan improves water quality and reduces environmental impacts everywhere downstream from its location. Because much of the sediment will be retained behind the structure, this program will avoid substantial downstream disposal site mitigation.	Toutle, Cowlitz

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syllabus	The recommended plan is a combination of a SRS (125-foot spillway) at the Green River site on the North Fork Toutle River, minimal levee improvements at Kelso, Washington, and dredging downstream from the SRS during its construction and in later years of the project when the reservoir has filled and sediment begins to pass over the spillway.	Toutle, Cowlitz

United 1984 Mount St. Helens, Washington, feasibility report & environmental impact statement : Toutle, Cowlitz and Columbia Rivers : final. USACE Call # - TC 530 .U543 1984

Page	Comment	Spatial
	Report chapters include Background; Updated Planning Considerations (sediment analyses); Further Investigations; National Economic Development Plan; The Preferred Plan; Staged Construction; Features Affecting Management Strategy Implementation; Summary of Public Involvement, Views and Comments; Environmental Impact Statement and Section 404(b) Evaluation; and Discussion, Conclusions, Recommendations.	

United Mount St. Helens, Washington, Toutle, Cowlitz and Columbia Rivers. Design memorandum no. 1, general design memorandum. USACE Call # - TC 202 .P67 M68 DM 1

Page	Comment	Spatial
ii (syllabus)	This General Design Memorandum presents three alternative solutions (single-stage SRS, multi-stage SRS, No SRS and dredging) for controlling sediment eroding from Mount St. Helens and the North Fork Toutle River Valley.	SRS site, NF Toutle

United 1987 Mount St. Helens, Washington, Toutle, Cowlitz and Columbia Rivers. Design memorandum no. 14, Kelso levee improvement. USACE Call # - TC 202 .P67 M68 DM 14

Page	Comment	Spatial
syllabus	DM 14 presents information pertaining to levee improvement at Kelso, Washington.	Kelso

United 1985 Mount St. Helens, Washington, Toutle, Cowlitz and Columbia Rivers. Design memorandum no. 2, SRS and staged SRS hydrology and meteorology. USACE Call # - TC 202 .P67 M68 DM 2

Page	Comment	Spatial
preface	DM 2 provides information pertaining to the single-stage and multiple-stage SRS alternatives.	SRS site

United 1986 Mount St. Helens, Washington, Toutle, Cowlitz and Columbia Rivers. Design memorandum no. 3, SRS sedimentation. USACE Call # - TC 202 .P67 M68 DM 3

Page	Comment	Spatial
1-2	DM 3 (a) summarizes the procedures and rationale used to forecast sediment movements; (b) defines the rate and pattern of sediment deposition upstream of the proposed SRS; (c) describes the schedules for, and quantities of, downstream	SRS, Toutle, Cowlitz

Author	Year	Title	
	Page	Comment	Spatial
United	**1986**	**Mount St. Helens, Washington, Toutle, Cowlitz and Columbia Rivers. Design memorandum no. 5, reservoir clearing and project roads. USACE Call # - TC 202 .P67 M68 DM 5**	
	i (synopsis)	DM 5 covers reservoir and sediment retention area clearing, and construction of project roads. Clearing is not considered cost effective and is not recommended. Standing trees, vegetation, and floatable debris within the reservoir and sediment retention area will be left in place.	SRS project area
United	**1985**	**Mount St. Helens, Washington, Toutle, Cowlitz and Columbia Rivers. Design memorandum no. 6, Toutle River SRS geology and foundations. USACE Call # - TC 202 .P67 M68 DM 6**	
	synopsis	DM 6 presents geology and foundation information pertaining to the site selected for a sediment retention dam on the North Fork of the Toutle River.	SRS site
United	**1986**	**Mount St. Helens, Washington, Toutle, Cowlitz and Columbia Rivers. Design memorandum no. 7, Toutle River SRS concrete materials investigations & construction techniques. USACE Call # - TC 202 .P67 M68 DM 7**	
	throughout	DM 7 presents concrete designs and concrete requirement for the SRS	SRS
United	**1987**	**Mount St. Helens, Washington, Toutle, Cowlitz, and Columbia Rivers. Design memorandum no. 15, SRS base-plus dredging. USACE Call # - TC 202 .P67 M68 DM 15**	
	syllabus	DM 15 documents the dredging program authorized to enhance flood protection levels for Cowlitz River communities. Base-plus dredging is a component of the three-phase (SRS, Kelso levee improvements, base-plus dredging) plan to provide a permanent solution to Mt. St. Helens sediment related damages.	Cowlitz
United	**1980**	**Mt. Saint Helens recovery operations, Cowlitz County, Washington, Columbia County, Oregon: final environmental impact statement. USACE Call # - TD 194.56 .P3 M61 1980**	
	I	Remedial dredging of Columbia River 40-foot navigation channel (Columbia River mile 63-72 and Cowlitz River mile 0-9.0), and advanced flood protection measures in the Cowlitz and Toutle River basins RM 0.0-21.5 - - Corrective measures in response to damages caused by the volcanic eruption of Mt.	Columbia, Cowlitz
	throughout	Discussion of alternatives, Toutle debris retention alternatives, existing conditions, etc.	Columbia, Cowlitz

Author	Year	Title	
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United	**1981**	**Mt. St. Helens eruption, Cowlitz County, Washington, Cowlitz and Toutle Rivers : fiscal year 1982 action plan. USACE Call # - TC 424 .W2 M687 1981**	
	throughout	Discussion of construction feasibility, Cowlitz River erosion control, Cowlitz and Columbia River sedimentation monitoring, debris retaining structures, excavation, Mossyrock storage, and sedimentation studies.	Columbia, Cowlitz
United		**Mt. St. Helens recovery [video recording]: the first decade. USACE Call # - GB 1399.8 .W2 M7 VIDEO**	
		Discussion of SRS outlet works and fish passage in conjunction with FCF.	FCF, SRS
		Video shows the response of government agencies to eruption. Highlights the Spirit Lake Tunnel project and culminates in SRS project design, construction, and dedication of 1990.	Columbia, Cowlitz
United	**1990**	**Numerical simulation of mudflows from hypothetical failures of the Castle Lake debris blockage near Mount St. Helens, WA. USACE Call # - TC 549 .N85 1990**	
	executive	The purpose of this study is to evaluate the hydraulic characteristics of mudflow events resulting from the hypothetical failure of Castle Lake and to examine the ability of the SRS to capture and pass such events through its emergency spillway for various initial conditions at Castle Lake and the SRS. More specifically, the study is to (1) determine if flows will exceed the present spillway capacity of the SRS, (2) determine if the SRS will be overtopped during various breaching scenarios, (3) estimate how the peak discharge in communities downstream from the SRS will be affected by the presence of the SRS, (4) evaluate the routing effects on the resulting mudflow hydrographs due to lowering the initial Castle Lake levels at the time of breaching, and (5) evaluate the performance of the SRS during these various events when the SRS is empty of water and sediment (existing conditions), or full of sediment deposits up to the spillway crest.	Toutle, Castle Lake
	I (from	The primary purposes of this study were to (1) evaluate the channel performance for existing conditions for the design mudflow event, (2) estimate wave runup for the mudflow on the upstream face of the proposed sediment retention structure, and (3) evaluate the adequacy of the spillway to pass clear water flows resulting from a mudflow event entering a reservoir full of water.	SRS
United	**1988**	**Sediment gradation analysis results, 1980-1988 : Mount St. Helens, Washington : Cowlitz River, Toutle River, North Fork Toutle River.. USACE Call # - GB 1399.8 .W2 S42 1988**	
	throughout	This document contains the sediment gradation analysis results for suspended sediment and bed material samples taken from 1980 to 1988 on the Cowlitz River, Toutle River, and N.F. Toutle River by Sedimentation Section, Hydraulics and Hydrology Branch, Engineering Division, Portland District U.S. Army Corps of Engineers, and other sections.	Cowlitz, Toutle, NF

Author	Year	Title	
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United	**1993**	**Sediment retention structure : Mount St. Helens sediment control Cowlitz, and Toutle Rivers, Washington : embankment criteria and performance report. USACE Call # - TC 425 .T6 S431 1993**	
	I	This technical report presents data on general, embankment, and foundation features and describes related events, problems, and decisions that occurred during construction and the initial operation of the Mount St. Helens SRS. This reports also provides an evaluation of the performance of the embankment dam based on design, construction, and operational conditions.	SRS
United	**1991**	**Sediment retention structure : Mount St. Helens sediment control, Cowlitz and Toutle Rivers, Washington : foundation report. USACE Call # - TC 425 .T6 S42 1991**	
	1-1	The purpose of this report is to provide a permanent record of the foundation condition found at the SRS site during construction. It includes summaries of the field investigations made prior to and during construction, site geology, foundation dewatering, foundation conditions under key features of the dam, temporary and permanent instrumentation, and possible areas of future problems.	SRS
United	**1983**	**A comprehensive plan for responding to the long-term threat created by the eruption of Mount St. Helens, Washington. USACE Call # - TC 424 .W2 U54 1983**	
	throughout	Presidential mandated Comprehensive Plan for long term solutions to eruption. Discussion of alternatives and indication of a course for implementation, and Corps of Engineers analysis of alternatives.	Columbia, Cowlitz
United	**1983**	**Annual Report FY 83 of the Chief of Engineers on Civil Works Activities.**	
		Reports budget and action information.	Columbia, Cowlitz
United	**1985**	**Columbia-Cowlitz-Toutle Rivers, Washington, restoration subsequent to Mt. St. Helens eruption. USACE Call # - TA 7 .C65 TR 13**	
	1	Document is the result of efforts to address questions: (a) how much sediment can be expected from the Toutle River during the upcoming flood season; (b) where in the Cowlitz and Columbia Rivers will deposition take place; and (c) what effect will deposition have of flood levels.	Columbia, Cowlitz
United	**1980**	**The economic effects of the eruptions of Mt. St. Helens : report to the Committee on Ways and Means of the U.S. House of Representatives on investigation no. 332-110 under section 332 of the Tariff act of 1930 / USITC. USACE Call # - HF 1756 .A5 1980**	
	23	Economic effects of the eruption of Mt. St. Helens on fisheries and fishery products: fish kill, hatcheries, fish habitat, commercial and sport interests, long-term effects.	Columbia, Toutle

Author	Year	Title / Comment	Spatial
Unknown	**2003**	**Elk Rock N1 Spillway Proposal 2003.**	
		The N1 spillway is a hardened weir that causes the NF Toutle River upstream reach to avulse through Hoffstadt and Bear Creeks to bypass N1.	NF Toutle
		Breaching the N1 spillway to correct grade would ensure that most high flow event energy is contained within the NF Toutle channel.	NF Toutle
		Because high flow event velocities would be reduced outside of the NF Toutle channel, sediment deposition would occur in these areas during high flow events.	NF Toutle
		The Elk Rock Sediment subarea is the primary sediment source for the NF Toutle River. The N1 Debris Structure spillway governs channel erosion and sediment transport in the Elk Rock Area.	NF Toutle
		Hoffstadt Creek would restore to historic production capacity if the N1 spillway is breached to correct grade level.	NF Toutle
		Breaching N1 spillway would change the Elk Rock subarea into a sediment deposit area, rather than a sediment source area.	NF Toutle
		High flow event sediment deposition would create a functioning NF Toutle floodplain and foster restoration of tributaries like Hoffstadt Creek in the Elk Rock Area.	NF Toutle
Unknown	**2000**	**Mt. St. Helens Riparian Enhancement Project Narrative IAC Project #06-2000**	
		Trees, shrubs and erosion control ground cover will also be planted to further increase stability, habitat diversity and provide a source for future natural wood recruitment into the	NF Toutle
		Some of the logs will be anchored about every one hundred feet by partially burying them from the bank. Engineered log jams will also be placed in order to help prevent avulsions from reoccurring.	NF Toutle
		This project will result in increased stability within the Toutle River floodplain. This should provide increased protection of existing elk winter range habitat and aid in the long-term recovery of instream habitat for listed fish both on-site and in areas downstream.	NF Toutle
		This increased stability over an area of about 2.8 miles should also provide another long-term benefit by allowing an eventual reestablishment of vegetation and improvement of habitat conditions in an area encompassing hundreds of acres that had previously been eroded.	NF Toutle
		The objective of the project is to increase floodplain stability and decrease the potential for major erosive events in the future. Logs, root wads and other large wood will be obtained, transported to the site, and strategically placed along the eroded edge of the mudflow.	NF Toutle

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	Page	Comment	Spatial
USFS	**1997**	**Upper Toutle River Watershed Analysis. Gifford Pinchot National Forest, Mount St. Helens National Volcanic Monument. September, 1997.**	
	1	The Upper Toutle Watershed is divided into 9 sub-basins for analysis. The following issues are analyzed: Mass wasting; surface erosion from roads and upland slopes; fire history; vegetation structure and composition; sensitive and C-3 plant species; habitat condition for TES, C-3, and cavity-dependent animal species; hydrologic changes; water quality and key habitat attributes for resident and anadromous salmonids; completion of trail system and trail connectors; recreational road access; and resource impacts from recreation use.	Executive summary
	1	The Upper Toutle Watershed is divided into 9 sub-basins for analysis. The following issues are analyzed: Mass wasting; surface erosion from roads and upland slopes; fire history; vegetation structure and composition; sensitive and C-3 plant species; habitat condition for TES, C-3, and cavity-dependent animal species; hydrologic changes; water quality and key habitat attributes for resident and anadromous salmonids; completion of trail system and trail connectors; recreational road access; and resource impacts from recreation use.	Executive summary
USFWS	**1984**	**The impacts on fish and wildlife of proposed sediment control actions for the Toutle, Cowlitz, and Columbia River systems. United States Department of Interior. Region One, Fish and Wildlife Coordination Act Report, December 1984.**	
	ii (preface)	Analysis of project impacts on fish and wildlife based on (1) project information and engineering data received prior to November 30, 1984; (2) an appraisal of existing and projected resources; and (3) a project life of 50 years.	Toutle, Cowlitz
	iii	The paper discusses fish and wildlife under pre-eruption, eruption, and post-eruption conditions. Paper discusses future of fish and wildlife both with and without the sediment control projects.	Toutle, Cowlitz
Wade	**2000**	**Salmon and steelhead habitat limiting factors, WRIA 26 (Cowliz). Washington Department of Ecology.**	
	82	Although no stations have collected continuous stream temperature readings in the upper Toutle Subbasin since the eruption of Mt. Saint Helens, it is anticipated that streams are exceeding State Water Quality Standards (16° C) due to several factors.	Toutle
	144	One of the most significant factors limiting fish passage within the Toutle subbasin is the problem operating the fish collection facility when heavy sediment loads are moving through the SRS. Assessment and repair of this situation is critical to the recovery of Toutle River populations of anadromous salmonids.	FCF
	163	Habitats that need protection in the North Fork Toutle River include: Hoffstadt and Alder Creeks, the most productive tribs in the North Fork Toutle watershed and Upper Wyant Creek, which provides important low-gradient coho habitat.	NF Toutle

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144	Recommendations for addressing limiting factors in the Toutle River Subbasin include: Removal or alteration of the SRS would facilitate natural recovery of the North Fork Toutle and downstream systems. Water quantity and water quality problems within the Silver Lake watershed need to be addressed. Reduce road densities and the miles of stream adjacent roads within the subbasin, and assess the condition of abandoned roads in the upper Toutle subbasin. Replant degraded riparian areas with native conifers. Look for opportunities to enhance or restore off-channel rearing habitat.	Toutle
84	A number of habitat constraints still limit production within the subbasin including; limited floodplain, off-channel, and pool habitat, high width-to-depth ratios and poor riparian conditions that contribute to elevated stream temperatures, lack of instream cover and LWD, and unstable substrate conditions. Hydrologic immaturity and high road densities within the subbasin contribute to increased peak flows and additional channel instability. High road densities and numerous stream adjacent roads also contribute excessive amounts of fine sediment to stream channels. Access and water quality are two major limiting factors within the Silver Lake watershed.	Toutle
84	Predation and competition from other fish species potentially limits the production of salmon and steelhead within the Silver Creek watershed (Weyerhaeuser 1994). There are approximately 25-30 fish species within the watershed, and approximately one-half are non-native fishes introduced to provide a warm-water fishery.	Toutle
83	The Upper Toutle Watershed Analysis (USFS 1997c) found recovering from the 1980 eruption of Mt. Saint Helens. The analysis found that 55% of the subbasins in the area have the potential for increased peak flows of 10% or greater due to loss of the mature conifer vegetation component	Toutle
83	High suspended sediment loads and turbidity are considered major limiting factors within the North Fork and mainstem Toutle Rivers (TAG). These high suspended-sediment loads largely restrict the suitable spawning and rearing habitat within the North Fork Toutle watershed to tributary streams (TAG; Lucas 1986).	Toutle
82	Water temperatures often exceed state water quality standards near the mouth of the Green River at the Toutle River Hatchery (Haapala 1993).	Toutle
82	Stream water temperature is a major factor influencing the composition and productivity of aquatic systems in the upper Toutle Subbasin (USFS 1997c; USFWS 1984).	Toutle
82	Problem factors in the Toutle basin include loss of riparian vegetation in tributary streams, channel widening from the mudflows that traveled down the North and South Forks of the Toutle, and channel widening from the introduction of large amounts of tephra (USFS 1997c).	Toutle

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81	High road densities within the Toutle basin add to already elevated inputs of fine sediments to the stream channels.	Toutle
79	Heavy sediment loads in the North Fork will \ habitat for some time into the future.	NF Toutle
79	Reports Habitat Measurements for the upper Toutle (Pool %, Riffle %, Mean depth, Glide %)	NF Toutle
83	The streams are likely subjected to increased peak flows that can cause bed and bank scour and channel shifting to the detriment of egg and fry survival. Roading has added to increased peak flow concerns in the upper basin by increasing stream lengths in the watershed by 0-63% (USFS 1997c). Approximately 370 extra miles of stream network have been added in the upper watershed by roads (USFS 1997c).	Toutle
80	In the Silver Lake watershed off-channel and side channel habitat is largely lacking (Weyerhaeuser 1994).	Toutle
81	Fine sediments related to road erosion were identified as a problem within the Silver Lake watershed. Eroding ditches and the long lengths of roads that drain directly to the streams are major sources of fine sediments to streams. Fifty-nine specific road segments drain directly to streams, including 39 road lengths >400 feet, and 18 road lengths > 800 feet. Unvegetated cut slopes also contribute excessive fine sediments (Weyerhaeuser 1994).	Toutle
81	Spawning gravels are scare in the Silver Lake watershed. This is exacerbated by the lack of LWD and other storage elements in the watershed (Weyerhaeuser 1994).	NF Toutle
82	Lack of riparian cover is considered to be one major causes of elevated stream temperatures in many of the upper Toutle River Subbasin streams including along the Green River (Haapala 1997; Lucas 1985;USFWS 1984), Elk Creek (Lucas 1986), Bear Creek (Lucas 1986), North and South Forks of the Toutle, and Herrington Creek (TAG).	Toutle
82	Reports a riparian Conditions Summary in the Toutle River Subbasin	Toutle
83	Elevated water temperatures within Silver Lake watershed are also a concern especially within the lower reaches of Hemlock Creek, within a tributary to Sucker Creek, and within Outlet Creek (Weyerhaeuser 1994; Houpt et. al. 1994).	Toutle
80	Annual sediment discharges in the North Fork had not changed appreciably 5 years after the eruption (Lucas 1986).	NF Toutle
76	Reports a list of affected floodplain connectivity along a number of tributaries within the Toutle.	Toutle
80	The Sediment Retention Structure (SRS) on the North Fork was the major obstacle preventing natural recovery of both the North Fork and the mainstem Toutle downstream.	SRS

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	77		Reports a list of noted bank stability issues within the Toutle basin.	Toutle
	80		As it exists, the SRS has become the major chronic fine sediment source to downstream habitats / the SRS prevents or at least slows natural recovery of the system like what has been observed in the Green River and South Fork Toutle.	SRS
	78		Hoffstadt Creek and Bear Creek, and the North Fork Toutle all lack adequate supplies of LWD (Lucas 1986; TAG).	NF Toutle
	80		Sediments are often highly cemented with fines, and when redds are established they are often suffocated by excessive fines moving through the system.	Toutle
	75, 145		Reports a list of identified blockages in the Toutle River basin / One of the more significant culverts to assess and repair is on North Fork Wyant Creek (productive coho stream) where a culvert blocks passage at the 4531 Road crossing.	NF Toutle
	81		The lower reaches of many creeks contain excessive fine sediments including; Johnson, Wyant, Alder, Studebaker, and Bear creeks (TAG; Lucas 1986).	Toutle
	78		Within the Silver Lake watershed, functional LWD is scarce (Weyerhaeuser 1994; Houpt et. al. 1994). Riparian areas within the watershed on the whole do not now function as sustainable sources of LWD. Near term recruitment potential for LWD is low, owing to a predominance of alder with riparian stands. Fish habitat created by LWD is likely to be below potential for some time (Weyerhaeuser 1994).	Toutle
Warren	**1982**	**Come hell and high water : Mt. St. Helens and the federal response on the lower Cowlitz River: technical completion report. USACE Call # - QE 523 .S23 W3 1982**		
	iv (from		The mudflow and spoils have low agricultural potential; some land owners reaped windfall benefits from the dredging program; some form of program to protect the area from future flooding will be demanded and will involve structures rather than social adjustments.	Columbia, Toutle